# RIDE SPECIFICATION REVIEW FOR THE MONTANA DEPARTMENT OF TRANSPORTATION

FHWA/MT-06-004/8179

*Final Report*

*prepared for*
THE STATE OF MONTANA
DEPARTMENT OF TRANSPORTATION

*in cooperation with*
THE U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

*August 2006*

*prepared by*

Sirous Alavi
Michael P. Tavares
Nathan P. Andress

Sierra Transportation Engineers, Inc.

RESEARCH PROGRAMS

Montana Department of Transportation
MDT
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# RIDE SPECIFICATION REVIEW

# FOR THE

# MONTANA DEPARTMENT OF TRANSPORTATION

CONTRACT#: 307019

PROJECT #: 8179

PREPARED BY:

SIERRA TRANSPORTATION ENGINEERS, INC.
1005 TERMINAL WAY, SUITE 125
RENO, NV 89502

PREPARED FOR:

serving you with pride

MONTANA DEPARTMENT OF TRANSPORTATION
2701 PROSPECT AVENUE
P.O. BOX 201001
HELENA, MT 59620-1001

JUNE 2006

## TECHNICAL REPORT DOCUMENTATION PAGE

| | | |
|---|---|---|
| 1. Report No. FHWA/MT-06-004/8179 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>Ride Specification Review for the Montana Department of Transportation | 5. Report Date June 2006<br>6. Performing Organization Code | |
| 7. Author(s)<br>Sirous Alavi, Ph.D., P.E.<br>Michael P. Tavares, P.E.<br>Nathan P. Andress, E.I. | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address<br>Sierra Transportation Engineers, Inc.<br>1005 Terminal Way, Suite 125<br>Reno, NV 89502 | 10. Work Unit No.<br>11. Contract or Grant No.<br>Contract # 307019, Project # 8179 | |
| 12. Sponsoring Agency Name and Address<br>Research Programs<br>Montana Department of Transportation<br>2701 Prospect Avenue<br>PO Box 201001<br>Helena MT 59620-1001 | 13. Type of Report and Period Covered<br>Final Report<br>Research: July 2004 – January 2006<br>14. Sponsoring Agency Code 5401 | |

15. Supplementary Notes Research performed in cooperation with the Montana Department of Transportation and the US Department of Transportation, Federal Highway Administration. This report can be found at http://www.mdt.mt.gov/research/projects/const/ride_review.shtml.

16. Abstract

This report covers the activities that were performed to enhance the current Montana Department of Transportation (MDT) ride specification for flexible pavements. The project team reviewed the MDT ride specification for flexible pavements and compared it with current literature and state of practice. An extensive state-of-practice survey of other Departments of Transportation (DOT's) was conducted and the results were utilized to provide recommendations to MDT for improving its ride specification. This report provides detailed information on the review of MDT current ride specification, literature review, state-of-the practice survey, and recommendations for improvements. The recommendations cover the proposed improvements to the current ride specification, tolerances, project classification levels, analysis tools and indices, and methods of acceptance. As part of the recommendations, a series of new documents (i.e., Profiler Operations Manual, QC/QA Plan) have been developed to enhance future profile data collection and analysis. Based on the findings of this project, the project team have revised the document entailed "Method of Sampling and Testing (MT-422)" and the document "MDT Ride Specification For Flexible Pavement". An implementation plan has been developed and presented in this report to provide MDT with a road map for implementing the findings of this project.

| | | | |
|---|---|---|---|
| 17. Key Words<br>Montana, Ride Specification, Flexible Pavement, Inertial Profiler, Pavement Smoothness, International Roughness Index | | 18. Distribution Statement<br>Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161. | |
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages 291 | 22. Price |

ACKNOWLEGEMENTS

This project was sponsored by the Montana Department of Transportation (MDT). Special thanks to Ms. Sue Sillick, MDT Research Programs Manager, for providing continuous support and valuable input throughout the course of this project. The authors would also like to thank MDT Project Panel for their active participation in the conduct of this project and for providing valuable information and data to the project team. Special thanks to Mr. Patrick J. Klinepeter of MDT for fulfilling a numerous data requests on a very timely fashion.

Many states provided information that was vital for the completion of this project. The authors would like to especially thank, Dr. Shakir Shatnawi from the California Department of Transportation (Caltrans) and Mr. George Way, formerly of the Arizona Department of Transportation (ADOT) for their valuable input. We would also like to thank our team members, Dr. Tom Papagiannakis, Dr. Jorge Sousa, and Mr. Mark Belshe for providing valuable expertise through the course of this project.

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## ACRONYMS

| | |
|---|---|
| AASHTO | American Association State Highway and Transportation Officials |
| DMI | Distance Measuring Instrument |
| ETG | Expert Task Group |
| FHWA | Federal Highway Administration |
| IBM | International Business Machine |
| ICC | International Cybernetics Corporation |
| IRI | International Roughness Index |
| MDR | Mobile Data Recorder |
| MDT | Montana Department of Transportation |
| NHI | National Highway Institute |
| PI | Profile Index |
| PMS | Pavement Management System |
| PRI | Profilograph Roughness Index |
| SI | International System of Units |
| STE | Sierra Transportation Engineers, Inc. |

# 1.0 INTRODUCTION

Sierra Transportation Engineers, Inc. (STE) is pleased to provide this final report for Montana Department of Transportation (MDT) contract number 307019, titled "Ride Specification Review for the Montana Department of Transportation". This report provides detailed information about the project objectives, deliverables and findings. The format of this report follows the MDT Research Section Report Requirements dated January 5, 2006.

## 1.1 PURPOSE

The purpose of this project is to review the MDT asphalt ride specification and compare it with current literature and state of practice. Upon completion of this review, recommendations are to be made for improvements to the current ride specification.

## 1.2 SCOPE

The STE team developed a detailed work plan that entails the scope of activities necessary to successfully complete the project objectives. This report covers the activities that were performed during this project. The following specific activities were identified in the project work plan:

- Kick-Off Meeting,
- Task A. Review the State's Current Ride Specification,
- Task B. Literature Search,
- Task C. Conduct a State of the Practice Survey,
- Task D. Recommendations, and
- Task E. Implementation Plan.

## 2.0 KICK-OFF MEETING

Based on discussions with MDT Research Programs Manager, Ms. Sue Sillick, a kick-off meeting was scheduled for July 30th, 2004 in Helena to discuss the project activities in detail. Some of the key highlights of the kick-off meeting discussions were:

- The project focus should be on improving the current MDT ride specification for flexible pavements. The project focus is not investigating the overall factors influencing the smoothness of roads (which will require an in depth analysis of construction QC/QA practices, mix design, pavement deign, materials selection, pavement management system, etc.).
- STE should investigate whether an improved bump criterion or other analysis tools will help identify and locate "bumps".
- STE should investigate whether bump criterion should be implemented for areas 150 ft (45.72 m) adjacent to bridge decks.
- STE should investigate other classification types (e.g., AADT, functional class, etc) for the project classification scheme.
- STE should investigate whether 0.2 mile (0.32 km) distance is enough for acceleration of profiler for climbing and passing lanes.
- STE should investigate constraints of data collection along horizontal curves (i.e., 900 ft (274.32 m) radius taken from vendor operation manual).
- STE should make recommendations for a maximum IRI threshold above which a section should be subjected to corrective actions or rejected.
- MDT wants to keep current connection of density tests to the basis for smoothness pay factors.
- MDT did not want STE to attempt any modeling activities that relate increases/decreases in service life due to initial pavement smoothness. This work is being conducted under another MDT project.
- STE should develop template documentation for QC/QA and profile operations.

# 3.0 TASK A. REVIEW THE STATE'S CURRENT RIDE SPECIFICATION

## 3.1 BACKGROUND

STE's review of MDT's current ride specification involved the following activities:

- Review of MDT's current "Ride Specification for Flexible Pavement" document;
- Review of MDT document "Method of Sampling and Testing, MT-422: Method of Test for Surface Smoothness and Profile";
- Review of currently used analysis software; and
- Review of currently followed Quality Control/Quality Assurance procedures for data collection and analysis.

During this task, a series of data were received from MDT. These included:

- AADT for a series of projects from each project classification. STE utilized this information in its investigation of other alternate project classification schemes for ride specification as discussed in Tasks B and D.
- Data for a series of projects in ERD format (ERD refers to the Engineering Research Division of UMTRI or The University of Michigan Transportation Research Institute) and results from vendor software in 0.2 mile (0.32 km) increments. STE utilized this data in its investigation of alternate software for analysis of profile data and identification of "must grind" areas.
- A copy of vendor's operation manual. STE used the information in this manual in its efforts to recommend improvements to the existing QC/QA procedure and MT-422 for road profile data collection and analysis.
- Notes of the profile operating training that was conducted approximately 3 years ago by vendor. STE utilized this information in its efforts to develop more uniformity in the data collection and analysis procedures.
- STE also requested the current QC/QA check list used by profiler operators. STE was notified that currently there is no QC/QA check list. STE has developed a QC/QA check list for use by MDT technicians during activities related to profile testing to enhance data quality and documentation processes.

The following sections thoroughly discuss STE's activities under Task A.

## 3.2 MDT RIDE SPECIFICATION FOR FLEXIBLE PAVEMENT

The current ride specification for bituminous pavements was last revised in May, 2003 *(1)*. In its current form, this specification has all the necessary elements of a comprehensive specification and is more developed than the specifications of many other states.

Some of the key elements of the current MDT specification are different project classifications based on opportunities for improving ride, target IRI values for each project classification, a provision to provide courtesy testing to assist the contractor, use of a bump criterion to identify areas requiring corrective work, pay factors based on IRI, and payment based on unit price for each type of plant mix surfacing placed in a given section.

### *3.2.1 SURFACE SMOOTHNESS*

Surface smoothness is measured using the International Roughness Index (IRI). Profile data is collected with MDT's International Cybernetics Corporation (ICC) Class I Laser Profilers. ICC provided software is used to calculate IRI based on the raw profile data. The software being used has worked well for MDT; however, it is a DOS based program. STE requested and received a series of data files in ERD format from actual construction projects to compare the ICC software with other available software as described in Section 4.

In the current specification, IRI is determined on mainline travel lanes including paved bridge decks. Smoothness data is not evaluated for climbing & passing lanes less than 0.2 miles (0.32 km), turning lanes, acceleration & deceleration lanes, shoulder & gore areas, road approaches, horizontal curves with a 900 ft (274.32 m) radius or less in centerline radius, pavement within 150 ft (45.72 m) of bridge decks, approach slabs, and the terminal paving points of the project. A section is defined as a single paved lane with 12 feet (3.65 m) or greater width having a length of 0.2 miles (0.32 km). Partial sections are prorated or added to other sections.

The following issues are identified in the review of "surface smoothness" portions of the specification:

- Surface smoothness is discussed multiple times in the specification. The surface smoothness sections need to be consolidated.
- STE should investigate whether 0.2 miles (0.32 km) is enough distance for climbing & passing lanes as there is a need for acceleration & deceleration distance.
- STE should investigate constraints of data collection along horizontal curves (i.e., 900 ft (274.32 m) radius taken from vendor operation manual).
- STE should investigate exclusion distance for bridge decks, approach slabs, and terminal paving points.

Based on the findings of Literature Review (Task B), the State of Practice Survey (Task C), STE has made recommendations in Task D to fine-tune the thresholds set for the "excluded" areas in the current ride specification.

#### 3.2.1.1 PROJECT CLASSIFICATION SCHEME

In the current specification, target IRI values are determined by separating the projects into four classification schemes based on the number of opportunities for improving the ride, by the pre-paving IRI value, or by a combination of both as shown in Table 3.1.

The MDT project classification scheme is tied to construction activities as defined by the number of opportunities available for improving the ride quality. In the literature review of Task B and the state of practice survey of Task C, STE studied other project classification types relating the target IRI to posted speed, functional classification, and construction type. The results of STE's investigation are thoroughly discussed in Section 6.

*Table 3.1. Current Project Classification Scheme.*

| Project Classification | Target IRI (in/mi) [m/km] | Other Criteria | | |
|---|---|---|---|---|
| Class I | 46-65<br>[0.73-1.03] | 3 or More Opportunities | Pre-Pave IRI < 140 in/mi [2.21 m/km]<br>2 Opportunities | Pre-Pave IRI < 90 in/mi [1.42 m/km]<br>Single Lift Overlay |
| Class II | 55-75<br>[0.87-1.18] | | Pre-Pave IRI ≥ 140 in/mi [2.21 m/km]<br>2 Opportunities | Pre-Pave IRI > 90 in/mi [1.42 m/km] and < 140 in/mi [2.21 m/km]<br>Single Opportunity |
| Class III | 56-80<br>[0.88-1.26] | | | Pre-Pave IRI ≥ 140 in/mi [2.21 m/km] and < 190 in/mi [3.00 m/km]<br>Single Opportunity |
| Class IV | 61-90<br>[0.96-1.42] | | | Pre-Pave IRI > 190 in/mi [3.00 m/km]<br>Single Opportunity |

#### 3.2.1.2 EQUIPMENT

Each of the five districts in Montana has an ICC Class I Laser Profiler, which is used for smoothness determination at construction sites. These profilers are trucks that have two lasers and two accelerometers located in the wheel paths.

#### 3.2.1.3 PROJECT TESTING

MDT tests the pavement surface prior to seal & cover with a single profiler pass in each travel lane. The IRI for a lane is calculated using the average of data collected for each wheel path. The profile testing is performed within 3 working days and the results are ready for review within 2 working days. Since the pay factor is directly tied to IRI the main issue identified is whether a single run provides an accurate IRI for determining the incentive/disincentive pay factor. STE covers this topic in Task B and Task C.

However, the most critical aspect of accurately measuring IRI lies within the framework established for smoothness data collection and analysis. This framework is currently described in the MT-422 document *(2)* that covers the “Method of Test for Surface Smoothness and Profile”. As described later, STE thoroughly evaluated MT-422 and developed a series of documents to enhance the accuracy of IRI measurements and reporting procedures.

Pre-pave IRI is collected as close to contract letting as possible (i.e., usually less than six months prior to construction activities).

At the request of a contractor and with at least a seven calendar days notice to the MDT Project Manager, a one time courtesy smoothness and surface profile test will be provided by the Department. The section for testing should be no less than two and no more than three miles of continuous new pavement. Courtesy test results are informational only and are provided to aid the contractor in achieving the desired smoothness. The contractor interprets the courtesy test results and decides whether there is a need to modify the construction operations to reach the planned smoothness thresholds.

Discussions with MDT personnel indicated that this testing is working well for both the Department and the contractors. MDT has no problem conducting the requested test with a seven day notice.

#### 3.2.1.4 PAY ADJUSTMENT FACTORS

Table 3.2 shows the current MDT smoothness pay factors for flexible pavement construction. The pay adjustment factor is a function of project class and post construction IRI.

*Table 3.2. Current Pay Adjustment Factors versus MDT Project Class.*

| Project Classification | Actual IRI (in/mi) [m/km] | Pay Factor |
|---|---|---|
| Class I | < 40<br>< [0.63] | 1.25 |
| | 40 – 45<br>[0.63 - 0.71] | 1.10 |
| | 46 – 65<br>[0.73 – 1.03] | 1.00 |
| | > 65<br>> [1.03] | 0.80 |
| Class II | < 45<br>< [0.71] | 1.25 |
| | 45 – 55<br>[0.71 – 0.87] | 1.10 |
| | 56 * – 75<br>[0.88 – 1.18] | 1.00 |
| | > 75<br>> [1.18] | 0.80 |
| Class III | < 56<br>< [0.88] | 1.10 |
| | 56 – 80<br>[0.88 – 1.26] | 1.00 |
| | > 80<br>> [1.26] | 0.90 |
| Class IV | < 61<br>< [0.96] | 1.10 |
| | 61 – 90<br>[0.96 – 1.42] | 1.00 |
| | > 90<br>> [1.42] | 0.90 |

*Discrepancy in Ride Specification text and table was brought to attention of the MDT panel.

In its current form, pay adjustment factors for all classes are step functions. Figure 3.1 presents the shape of the step function for Class I projects.

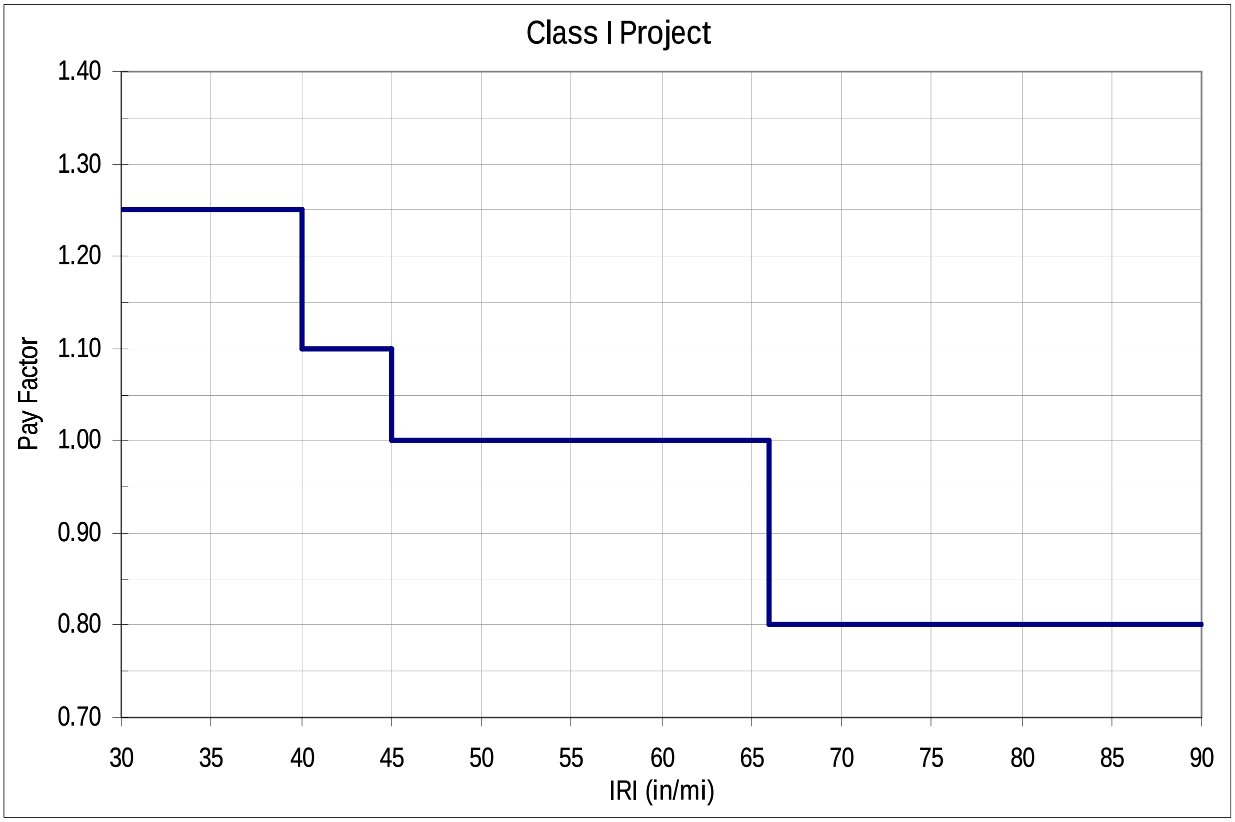


*Figure 3.1. Class I Project Pay Adjustment Factor Function.*

According to MDT personnel the target values for pay adjustment factor and IRI have performed well for MDT and the contractors. MDT and STE also agreed that the pay adjustment factor table should be kept as simple and practical as possible. Within this framework, STE has identified the following issues that have been investigated in Tasks B and C:

1. The current step function creates several plateaus within which a range of IRI values receive the same pay adjustment factor. STE believes that this was designed to take into account the variability in IRI measurements. However, the current step function results in a wide range of IRI (i.e., for Class I 46-65 in/mi (0.73-1.03 m/km), for Class II 56-75 in/mi (0.88-1.18 m/km), for Class III 56-80 in/mi (0.88-1.26 m/km), and for Class IV 61-90 in/mi (0.96 – 1.42 m/km)) receiving a pay adjustment factor of 1.00. The step function also results in sudden jumps (increase or decrease) of pay adjustment factor in a relatively narrow range in IRI. For example, in Class I, an IRI of 46 in/mi (0.73 m/km) receives a pay adjustment factor of 1.00 while an IRI of 43 in/mi (0.68 m/km) receives a pay adjustment factor of 1.10 or an IRI of 39 in/mi (0.62 m/km) receives a pay factor of 1.25. STE has investigated the possibility of

using a more gradual pay adjustment factor model (e.g., linear or non-linear) as part of its investigations in Tasks B and C. STE has made recommendations in Task D.

2. The current specification does not specify a maximum IRI value above which corrective actions need to be taken. For Class I any IRI above 65 in/mi (1.03 m/km) and for Class II any IRI above 75 in/mi (1.18 m/km) will receive a disincentive pay adjustment factor of 0.80. For Class III any IRI above 80 in/mi (1.26 m/km) and for Class IV any IRI above 90 in/mi (1.42 m/km) receives a disincentive pay adjustment factor of 0.90. It may be the case that due to good contractors and high quality of construction practices, MDT has not experienced situations where a contractor has taken the disincentive and left MDT with a very rough road. There is one area of current specification that provides some protection for the Department, which states, "*if more than 10 percent of the ride sections are subject to price reductions no other sections will qualify for a pay factor greater than 1.00*". However, STE believes there needs to be a maximum IRI threshold above which corrective actions or total rejection of the constructed section should be considered. STE's recommendations are described in Task D.

#### 3.2.1.5 Basis of Payment

Once the pay adjustment factor is determined for a project it is applied to the unit price for each type of plant mix surfacing placed in each section. The quantity of surfacing for each section is calculated as follows:

$$Quantity = (L \times W \times D) \times Unit\ Weight$$

Where:

*L* = Length of the lot measured.
*W* = *W*idth of the travel lane measured.
*D* = Depth of the entire bituminous surfacing section placed.
*Unit Weight* = 98% of mix design bulk density for each type of bituminous surfacing (when accepting density with a nuclear gauge).
*Unit Weight* = 93% of Rice Gravity from the mix design for each type of bituminous surfacing (when accepting density by core method).

Other components of the current incentive/disincentive program are that the corrected profile defects are not reevaluated for pay adjustment and the quality incentive allowances are used to offset any price reductions for progress estimates. Any quality incentive allowance remaining after all price reductions have been deducted is paid as a lump sum when all work on the item is complete.

#### 3.2.1.6 Inclusion of Density Criteria

The current specification ties density to the pay adjustment factor for smoothness. It states that *"if more than 10 percent of the density tests do not meet minimum plant mix pavement density requirements" no ride sections will qualify for a pay factor greater than 1.00".* During the kick-off meeting, STE discussed the issue that smoothness is a functional characteristic while density, particularly when there are high air voids, is a structural issue that should be dealt with under a separate quality incentive/disincentive with consideration to durability and aging characteristics.

MDT indicated that they do not want the density criteria removed from the specification because without this tie contractors may just target the ride incentive and neglect the density incentive. The current system ties different aspects of the project together and has worked well for MDT.

### *3.2.2 SURFACE PROFILE*

In the current specification, the surface profile criterion is to correct surface profile defects having a Profile Index (PI) greater than 0.4 inches (10 mm) in a distance of 25 feet (7.62 m). Currently MDT uses the profilers to measure pavement roughness profile, using a distance increment of 4.5 inches (12.44 cm). MDT utilizes the ICC supplied software, called RP090L, to compute IRI for pay adjustment factor determination and for simulating the California Profilograph trace. In turn, MDT utilizes ProScan (Kansas State University patented software) via a module in the ICC supplied software for automatically reducing the simulated California Profilograph for determination of must grind areas. Some of the MDT personnel indicated that locating a bump using the PI criterion is sometimes difficult. MDT personnel also indicated that the current PI specification was overly sensitive at times.

The use of ProScan software to measure PI as the criterion for must grind immediately became an issue for STE team. It has been STE's understanding, which later was confirmed by the ProScan developers at Kansas State University, that the bump finder module of ProScan is independent of its PI calculations and therefore independent of the blanking band width. With this in mind, STE believes that the reference to PI and blanking band should be removed from the MDT ride specification. The revised specification should state "…correct surface profile defects of greater than 0.4 inches (10 mm) in a distance of 25 feet (7.62 meters)..."

*PI Calculations in ProScan Software* – ProScan software can automatically reduce the simulated California Profilograph trace into the Profilograph Roughness Index (PRI) (also referred to as PI). This is done in increments of 492 feet (150 m). The PRI is computed as the accumulated departures of the trace per distance traveled above or below the blanking band, (i.e., bumps and dips, respectively), referred to as "scallops". This procedure is shown schematically in Figure 3.2.

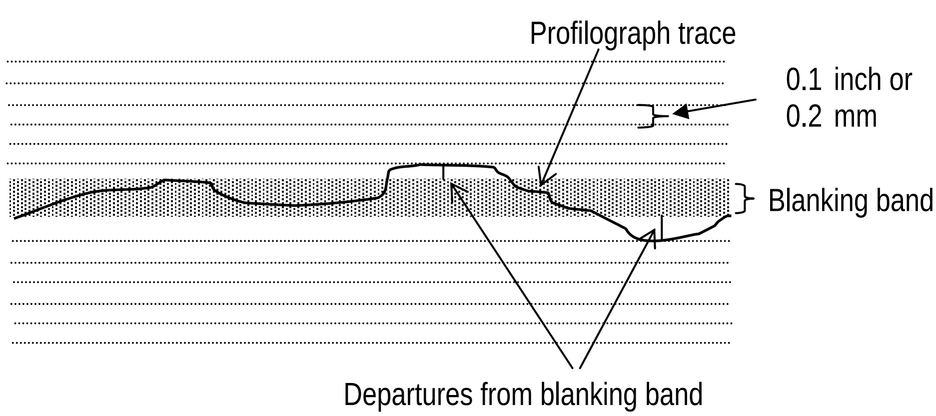


*Figure 3.2. Schematic of the PRI Computation & Bump Identification.*

*Bump Identification in ProScan Software* – In the ProScan software the Kansas test method for profiling is automated. In the Kansas test method, similar to many other agencies, bumps and dips are determined manually from a profile trace using a plastic template. It has a line one inch (25 mm) long scribed on one face with small holes or scribed marks at either end, and a slot, the specified bump height, from and parallel to the scribed line (Figure 3.3). The one inch (25 mm) line corresponds to a horizontal distance of 25 ft (7.62 m) on the horizontal scale of the profile trace.

To find high points in excess of the specified bump height, each prominent peak or high point on the profile trace is located then the template is placed so that the small holes or scribe marks at each end of the scribed line intersect the profile trace to form a chord across the base of the peak or indicated bump.

With a sharp pencil a line is drawn using the narrow slot in the template as a guide. Any portion of the trace extending above this line will indicate the approximate length and height of the deviation in excess of the specified bump height.

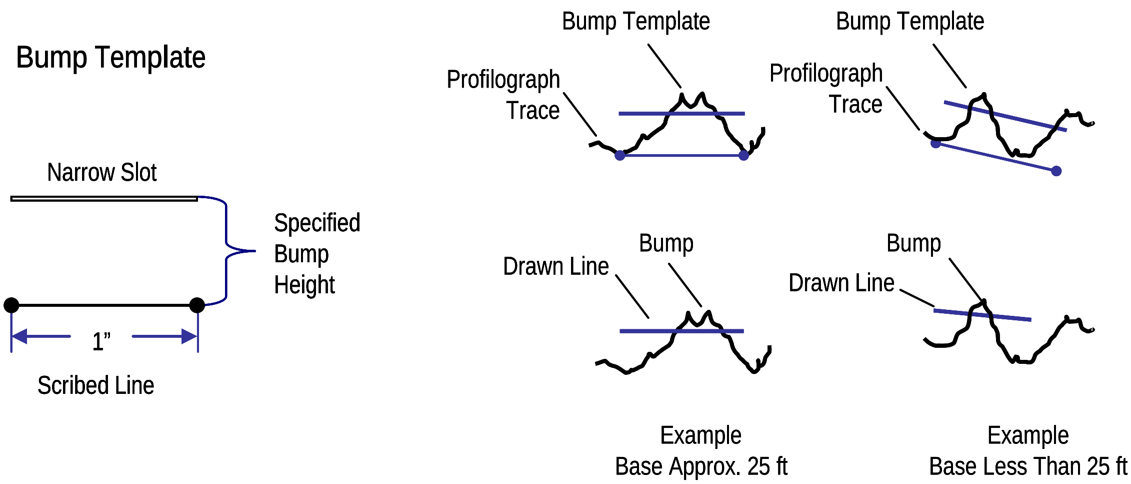


*Figure 3.3. Schematic of a Bump Template Automated in ProScan.*

ProScan identifies must grind / fill of bumps / dips in terms of the km-post and a parenthesis that includes three pieces of information, namely, b/d for bump or dip, 1/2 indicating 1$^{st}$ or 2$^{nd}$ wheel path and the segment from the start, respectively. For example, 17+977.8 (b,1,1) means that there is a defect at km post 17977.8, it is a bump, in the 1$^{st}$ (i.e., right side) wheel path and it belongs to the first segment.

The standard MDT practice for establishing the spatial reference of the profile trace is through reflective tapes or cones marking the beginning and end of a profiling section. These are automatically recorded by the profiler data acquisition system. In addition, manually entered event markers are used to identify the start/end of the profiled sections.

According to the MDT personnel, when a zero starting point is used, the Project Managers are able to drive to the exact locations of the "must grind" area. However, if the profiler operator uses stationing in place of zero starting point locating the bump becomes difficult at times. This is because section points are set using the centerline of the road. During profiling, the differences of the DMI distances do not stay consistent with stationing measured at the centerline.

#### 3.2.2.1 Correction of Surface Profile Defects

Surface profile defects having a surface defect greater than 0.4 inches (10 mm) in a distance of 25 feet (7.62 m) need to be corrected by the contractor within 30 calendar days of notification but prior to seal and cover operations. Milling and filling operations can be used for deficient pavement depths and diamond grinding for excess pavement depths. Corrected surface profile defects will be tested and reevaluated. However, correction of profile defects will not be cause to reevaluate any section for surface smoothness.

## 3.3 METHOD OF TEST FOR SURFACE SMOOTHNESS AND PROFILE (DOCUMENT MT-422)

The MT-422 document describes the method of test for surface smoothness and profile specifically using an ICC profiler *(2)*. It describes the calibration procedures and step by step procedures for the subsequent project testing.

Each MDT District has a calibration site, where the distance was surveyed. There was a training class conducted by the profiler vendor about three years ago for the MDT profiler operators. During that training class, various files were created by the vendor to facilitate data processing and profiling operations. According to MDT personnel, some portions of MT-422 are outdated. In addition, there is no formal QC/QA plan for calibration, data collection, and data reporting procedures.

The MT-422 document needs updating to mirror current MDT practices and to utilize recommendations adopted from this study. Based on the information received from MDT on various aspects of calibration, data collection, and data processing, STE developed draft documents that were submitted to MDT in December 2005 for review. These draft documents (i.e., Profiler Operations Manual & QC/QA Plan) are intended to be a framework for MDT to enhance the quality of data collection and analysis procedures. These documents are discussed in Task D.

STE revised MT-422 (Appendix D) to complement the Profiler Operations Manual (Appendix E) and QC/QA Plan (Appendix F). Together, these documents can be used as a comprehensive profiling program for data collection and analysis on Montana's flexible pavements.

# 4.0 TASK B. LITERATURE SEARCH

## 4.1 INTRODUCTION

There exists an overwhelming amount of information available on smoothness, profile, and ride specification in the literature. STE's focus was to conduct a literature search to enhance the current MDT ride specification. Under this task, STE looked for information on ride specifications & tolerances, available software & indices, method of acceptance, QC/QA procedures, and incentive/disincentive levels.

Over seventy documents related to ride specification were collected and reviewed. Of utmost importance was the information obtained from other agencies' specifications that were utilized to make recommendations to MDT under Task D. These documents included the latest available ride specifications for over thirty agencies including Alabama, Alaska, Arizona, Arkansas, California, Colorado, Delaware, District of Columbia, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, Texas, and West Virginia.

These specifications were reviewed and compared with the current MDT ride specification to determine ways to enhance it. It has become clear to STE that MDT's current specification already has all the necessary elements of a successful specification. The impetus was to find ways to improve the current specification based on the issues identified in Task A and discussions with MDT.

Several of the available literature contained survey questions that were studied for possible inclusion in Task C survey questions *(3,4)*. In addition, STE reviewed the AASHTO provisional standards developed by FHWA and an Expert Task Group (ETG) namely: MP11-3 Profiler Equipment Specification *(5)*, PP 37-04 Determination of IRI to Quantify Roughness of Pavements *(6)*, PP49-03 Profiler Certification Program *(7)*, PP50-30 Smoothness Measurement Test Methods *(8)*, and PP51-03 Pavement Smoothness Specification *(9)*.

## 4.2 RIDE SPECIFICATIONS & TOLERANCES

### *4.2.1 PROJECT CLASSIFICATION*

As discussed in Task A, the current MDT project classification scheme is based on the number of opportunities to improve the ride, by the pre-paving IRI, or a combination of both. The current classification scheme consists of four different project classifications. A review of the literature including the specifications of over thirty other agencies revealed that there were no set criteria for defining projects classifications.

For most agencies, project classifications were separated by pavement types (i.e., AC or PCC). Besides this general commonality, the classification schemes varied by:

- Functional Class,
- Posted speeds,
- Traffic volumes,
- Number of opportunities to improve rides, or
- A combination of two or more of the above.

Figure 4.1 shows a combination of survey results of Task C with gathered information from the agency specifications under Task B. The presented information is limited to agencies that use IRI in their ride specification and either test using high speed or lightweight profilers. These agencies included Connecticut, Georgia, Kentucky, Louisiana, Maine, Maryland, New Mexico, New York, Pennsylvania, Tennessee, Texas, Vermont, Virginia, Washington, and Wyoming.

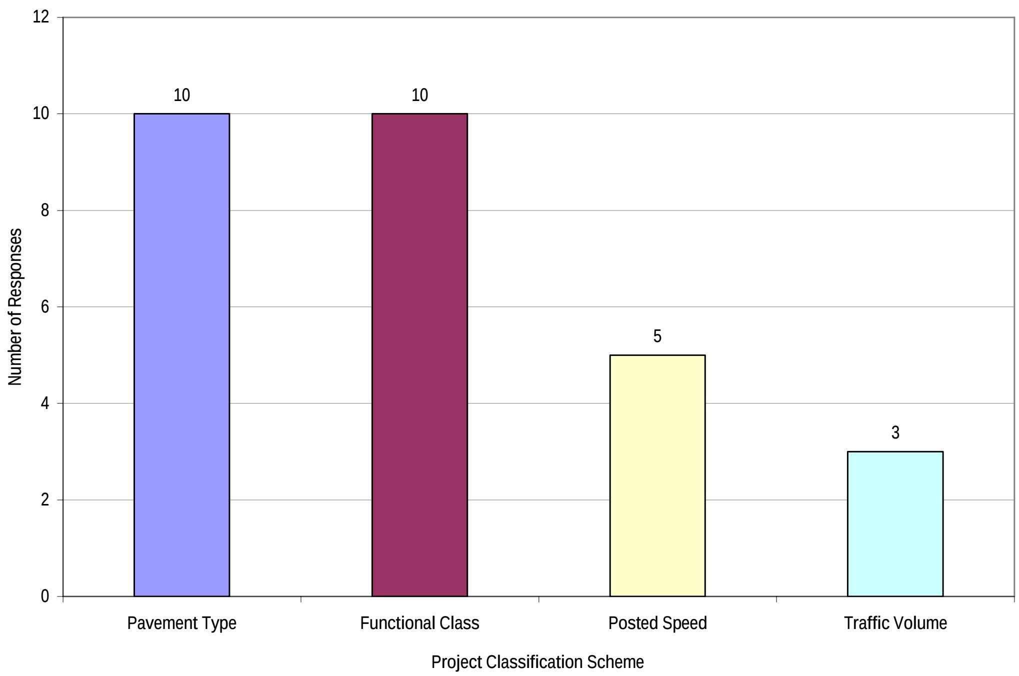


*Figure 4.1. Project Classification Schemes.*

From the literature review, it is clear that agencies have developed the type and number of classes based on their local experience of what really works for them given their agencies' specific characteristics. For example, it is not recommended for MDT to define the classes by traffic volumes as many critical roadway segments in Montana carry less traffic than other roadways in the country. Nevertheless, those roadway segments are as important to Montana's transportation network as their counterparts in other agencies.

Traffic volumes, posted speeds, and functional classifications are also not independent of each other as generally higher functional classes carry more traffic and have higher posted speeds than lower functional classes.

#### 4.2.1.1 Number of Opportunities for Improving Ride

MDT Project classifications are tied to the number of opportunities to improve ride. There are other agencies that use a similar concept for defining ride specifications. Table 4.1 presents the number of opportunities defined by four agencies that use inertial profilers to determine IRI.

The general rule of thumb is that IRI can be reduced by half with each opportunity. For the current MDT Class IV projects with pre paving IRI's over 190 in/mi (3.00 m/km), it would be difficult under this conventional wisdom to achieve the target IRI of 61-90 in/mi (0.96-3.00 m/km) specified in the current ride specification.

Many agencies believe that two opportunities are enough to achieve their ride specification requirements. Ultimately, the number of opportunities is dependant on the pre-paving road condition and also the local construction practices. This topic is further described in Task D and recommendations are made for number of opportunities that should be available per project classification.

*Table 4.1. Project Classification as Function of Number of Opportunities.*

| Agency | Number of Opportunities |
|---|---|
| Louisiana | Louisiana has three categories: A, B and C.<br><br>Category A (Multi-Lift New AC, Overlay > 2 lifts, All Interstates)<br>Category B (Overlay 2-1 lift over cold planed, 2 lift over existing)<br>Category C (1 lift over existing) |
| New York | New York has two categories: Level 1 and Level 2.<br><br>Level 1 (Interstate with at least two courses of HMA)<br>Level 2 (either an Interstate with one course of HMA or Non-Interstate receiving at least 2 courses of HMA) |
| Pennsylvania | Pennsylvania has two categories:<br><br>Expressway using 3 operations<br>Expressway using 2 operations & non-expressway using 2 or more operations |
| Texas | Texas has categories: Schedule 1, Schedule 2 and Schedule 3.<br><br>Depending on the type of construction, type of road, posted speed, and number of opportunities a pay adjustment schedule is chosen by TXDOT. |

#### 4.2.1.2 MAXIMUM IRI LIMIT

The current specification does not have any provisions for a maximum acceptable IRI above which either a corrective action or even the total rejection of a section is required. During the literature search, STE investigated the limits of many agencies. This topic was also discussed in Task A.

Table 4.2 represents the summary results of IRI limits in several agencies' specifications that use inertial profilers. Figure 4.2 is a graphical presentation of IRI limits set by those agencies and shows that the limit varies for different classification schemes and ranges between 65 in/mi (1.03 m/km) and 110 in/mi (1.74 m/km).

*Table 4.2. Maximum IRI Threshold for Various Project Classifications.*

| | Maximum IRI (in/mi) [m/km] Threshold for Project Classifications | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | No Maximum | Greater Than 45 mph | Lower Than 45 mph | Category A | Category B | Category C | Level 1 | Level 2 | No Category | Interstate | National Highway Routes | US and State Routes | Non-Interstate | Other Highways |
| Connecticut | No | | | | | | | | | | | | | |
| Georgia | No | | | | | | | | | | | | | |
| Kentucky | | 76 [1.20] | | | | | | | | | | | | |
| Kentucky | | | 86 [1.36] | | | | | | | | | | | |
| Louisiana | | | | 75 [1.18] | | | | | | | | | | |
| Louisiana | | | | | 89 [1.40] | | | | | | | | | |
| Louisiana | | | | | | 110 [1.74] | | | | | | | | |
| Maine | | | | | | | | | | | | | | |
| Maine | | | | | | | | | | 79 [1.25] | | | | 89 [1.40] |
| Maryland | No | | | | | | | | | | | | | |
| New Mexico | | | | | | | | | | 67 [1.06] | | | | |
| New Mexico | | | | | | | | | | | 69 [1.09] | | | |
| New Mexico | | | | | | | | | | | | 79 [1.25] | | |
| New York | | | | | | | 95 [1.50] | | | | | | | |
| New York | | | | | | | | 105 [1.66] | | | | | | |
| Pennsylvania | | | | | | | | | 70 [1.10] | | | | | |
| Texas | | | | | | | | | 95 [1.50] | | | | | |
| Virginia | | | | | | | | | | 100 [1.58] | | | 110 [1.74] | |
| Wyoming | No | | | | | | | | | | | | | |

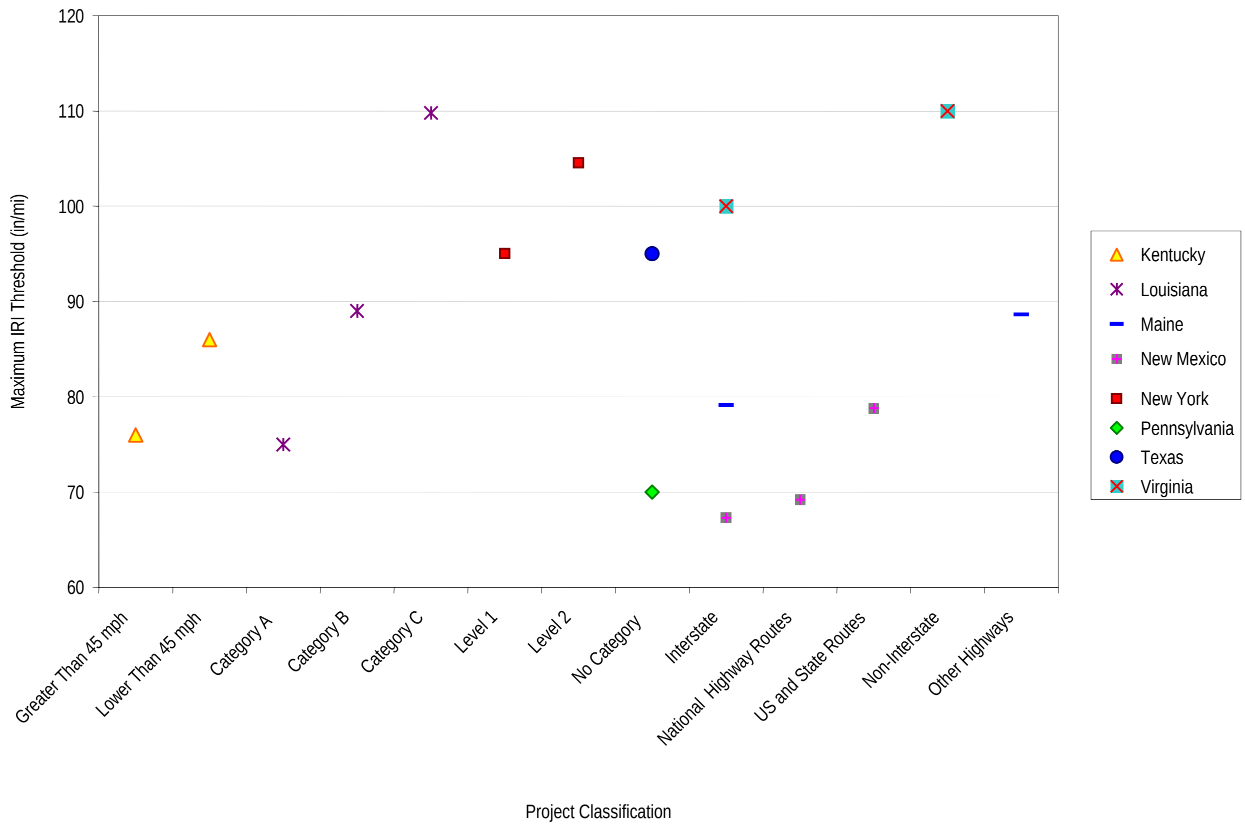


*Figure 4.2. Maximum IRI Threshold for Project Classifications.*

#### 4.2.1.3 Methods of Acceptance

As described in Task A, MDT utilizes a simulated California profilograph trace to identify profile defects using ProScan software with a "must grind" value of 0.4 inches (10 mm) in a distance of 25 ft (7.62 m).

STE combined the results of state of the practice survey with its literature review of agency specifications to develop Figure 4.3. It presents the current surface profile tolerance of 35 agencies in the U.S. Not all the agencies shown in this figure use a simulated profilograph for identifying the bumps or dips. Many of them use the straightedge method for identifying the profile defects. As shown in Figure 4.3, most agencies accept profile defects less than 0.3 inch (7.6 mm) in 25 ft (7.62 m) followed by 0.125 inch (3.2 mm) in 10 ft (3.048 m).

As shown in Figure 4.4, most agencies are using a 0.2 inch (5 mm) blanking band while some agencies are using a 0.0 or 0.1 inch (2.54 mm) blanking band. When comparing the results with previous surveys, there has been a move toward the zero blanking band in the desire to improve short wavelength pavement roughness. MDT currently uses a zero blanking band for determining PI; yet, this blanking band has no affect on identifying bumps or dips as discussed earlier.

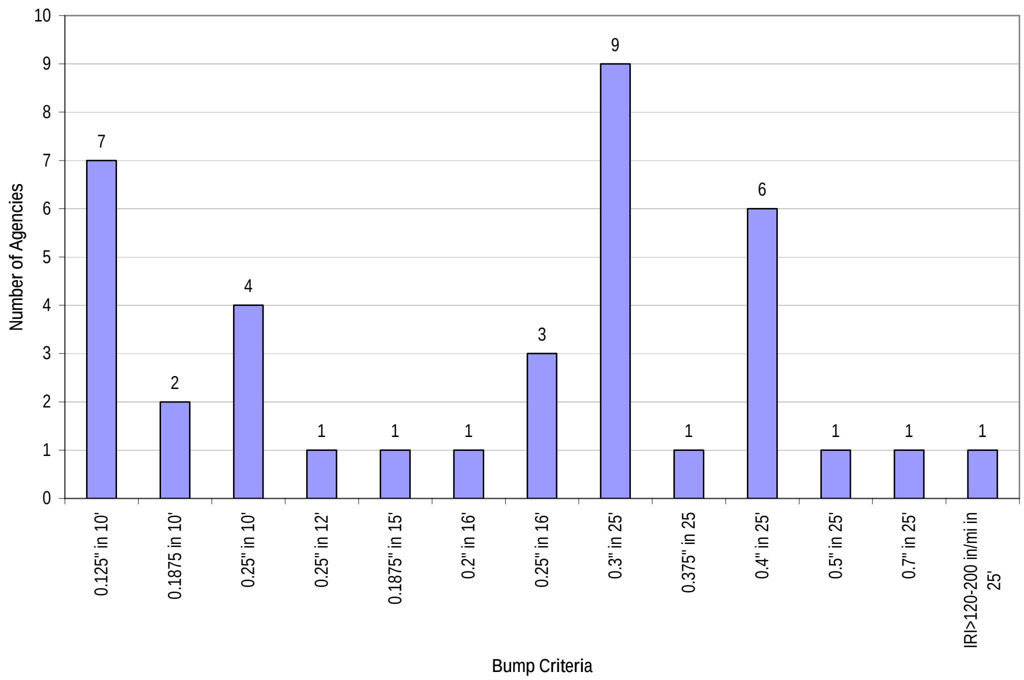


*Figure 4.3. Bump Size and Base Length for Agencies.*

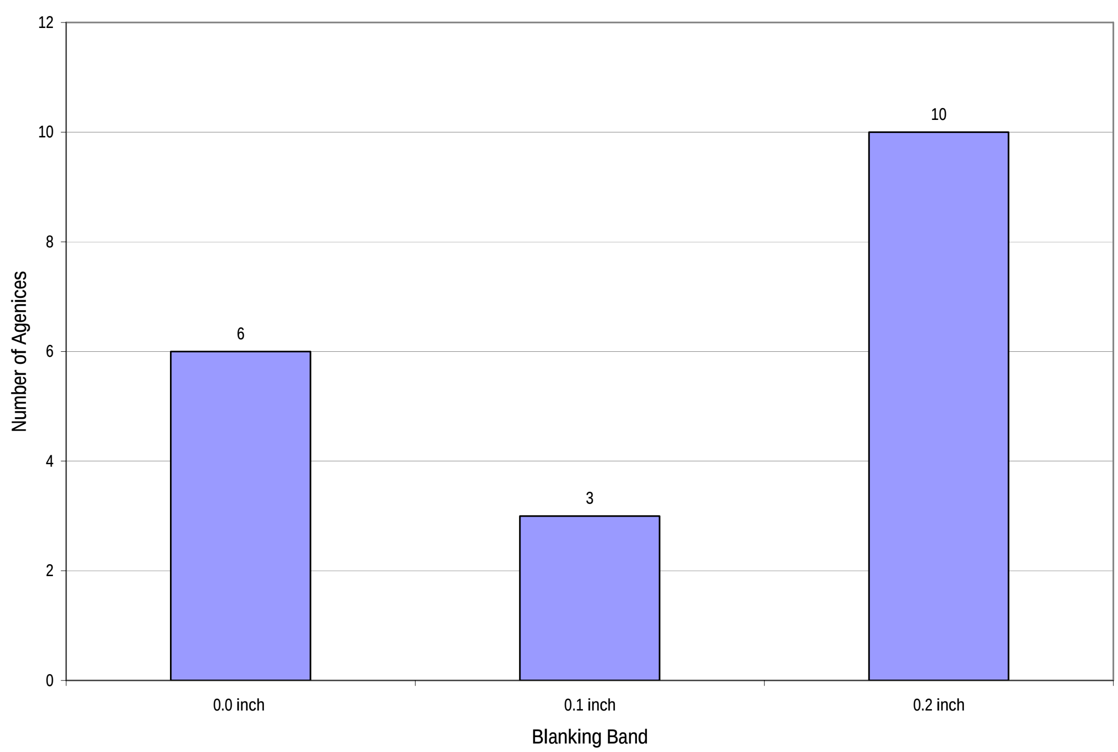


*Figure 4.4. Type of Blanking Band.*

4.2.1.4 DISINCENTIVE / INCENTIVE LEVELS

The results of STE literature search and also the state of practice survey shows that the majority of agencies with incentive / disincentive programs base their pay adjustment factors on a portion of unit bid price, which is consistent with the current MDT ride specification. In the following example, STE focused on the pay adjustment factor relationships of agencies that:

- Determine their incentive / disincentive payments by portion of unit bid price.
- Use an inertial profiler.
- Use IRI in their pay adjustment factor equation.

Figure 4.5 and Table 4.3 show that MDT has the highest pay factor adjustment for the agencies identified.

During the kick-off meeting, MDT personnel stated that the target rates for pay adjustment factors have worked well for MDT and its contractors. STE has made recommendations in Task D regarding MDT's pay adjustment factors without proposing drastic changes in rates.

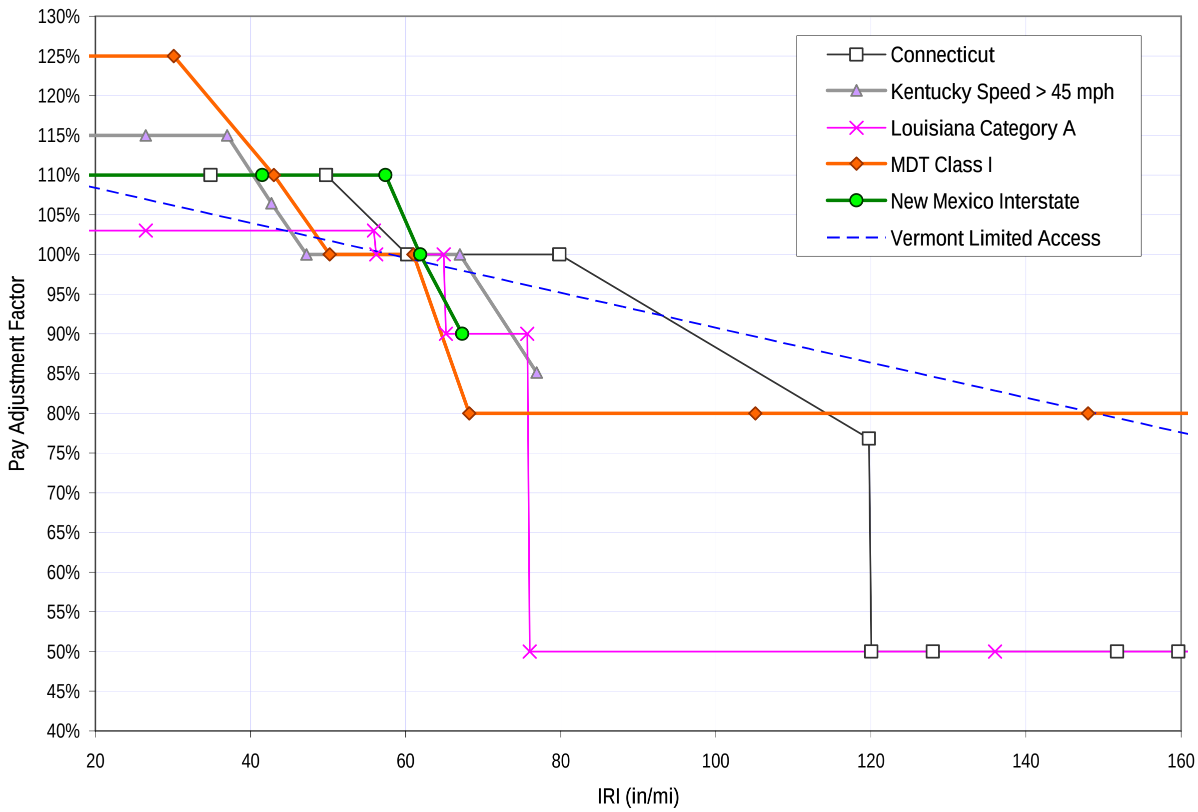


*Figure 4.5. Select Agency Category Pay Adjustment Factor Relationships.*

*Table 4.3. IRI at Minimum & Maximum Pay Adjustment Factors.*

| Agency | Category | Max PF | IRI (in/mi) [m/km] at Max PF | Min PF | IRI (in/mi) [m/km] at Min PF |
|---|---|---|---|---|---|
| Connecticut | - | 1.10 | 50 [0.79] | 0.50 | 120 [1.89] |
| Kentucky | Roads Posted Speed Greater Than 45 mph | 1.15 | 36 [0.57] | 0.85 | 77 [1.22] |
| Kentucky | Roads Posted Speed 45 mph or Less | 1.15 | 36 [0.57] | 1.00 | 86 [1.36] |
| Louisiana | Category A | 1.03 | 55 [0.87] | 0.50 | 75 [1.18] |
| Louisiana | Category B | 1.03 | 65 [1.03] | 0.50 | 89 [1.40] |
| Louisiana | Category C | 1.03 | 75 [1.18] | 0.50 | 110 [1.74] |
| Montana | Class I | 1.25 | 40 [0.63] | 0.80 | 65 [1.03] |
| Montana | Class II | 1.25 | 45 [0.71] | 0.80 | 75 [1.18] |
| Montana | Class III | 1.10 | 56 [0.88] | 0.90 | 80 [1.26] |
| Montana | Class IV | 1.10 | 61 [0.96] | 0.90 | 90 [1.42] |
| New Mexico | Interstate | 1.10 | 58 [0.92] | 0.90 | 67 [1.06] |
| New Mexico | National Highway Routes | 1.10 | 56 [0.88] | 0.90 | 69 [1.09] |
| New Mexico | US & New Mexico Routes | 1.10 | 47 [0.74] | 0.90 | 79 [1.25] |

## 4.3 AVAILABLE SOFTWARE & INDICES FOR ANALYZING ROADWAY PROFILE

Computers process profile data to calculate various profile indices that agencies require for pavement acceptance and incentive/disincentive programs. Computers have made it possible to reduce profile data fast, which is important due to the economics of construction.

The software programs used by agencies are generally developed by the equipment manufacturers/vendors. These software programs have different user interfaces; however, they utilize similar indices and algorithms. Equipment manufacturers use published and recognized standards to compute the various statistics and indices requested by agencies. Some of the equipment manufacturers for inertial profilers include: International Cybernetics Corporation (ICC), Dynatest, Pathway, Roadware, and Surface Systems & Instruments (SSI). As stated before, MDT currently uses ICC profilers.

### *4.3.1 ROAD PROFILE INDICES*

The following is a discussion of the two most commonly used indices by agencies for pavement acceptance as shown in literature and the survey performed under Task C.

The *International Roughness Index (IRI)* was originally developed for the World Bank based on a continued research effort from an NCHRP Project *(10)*. It is a roughness measure that has been demonstrated to be reproducible with a wide variety of equipment, including single and two track profiling systems, rod and level, and response type road roughness measuring systems.

Since the World Bank published guidelines for conducting and calibrating roughness measurements, the IRI has been adopted as a standard in several countries around the world, including the United States and Canada. The FHWA has also adopted IRI to evaluate the smoothness performance of LTPP pavement test sections.

IRI is defined as an index resulting from a mathematical simulation of vehicular response to the longitudinal profile of a pavement using a 'quarter-car' simulation model and a traveling speed that is typically 50 mph. The roughness scale is stable, transportable, relevant, and readily measurable by pavement engineers.

The basic steps to compute IRI are:

1) The profile data is filtered with a moving average having a 10 in (250 mm) base length. This is a low pass filter that smoothes the profile by attenuating the short wavelengths. The moving average filter should be omitted if the profile has already been filtered by a moving average or with an anti-aliasing filter whose cut-off attenuates wavelengths shorter than 2 ft (0.6m).
2) Quarter car simulation is performed on the profile. The parameters of the quarter car are defined in the IRI standard. The quarter car simulation on the profile is performed for a simulated speed of 80 km/h (50 mph) and the suspension motions of the quarter car are accumulated.
3) Compute IRI. The absolute values of the suspension motion that are obtained from the simulation are summed and then divided by the profile length to obtain the average suspension motion over the simulated length. The value that is computed is the IRI and has units of slope with the most common units being inches per mile or meters per km.
4) Calculate the mean IRI. The IRI is obtained for each wheel path. The average of these two values is referred to as the mean IRI and presents an overall view of the roughness of the roadway.

The IRI scale ranges from 0 to 1000 in/mi (0 to 16 m/km) with 0 in/mi being a perfectly smooth road and 1000 in/mi a road that is impassable condition. Typical ranges for IRI data collected on the FHWA LTPP project are from 40 to 300 in/mi (0.63 to 4.73 m/km).

*Profile Index (PI)* was originally obtained off a trace taken from a mechanical profilograph *(11)*. This trace was reduced by a rater, which could be subjective as well as tedious. Computer systems were developed that would scan a trace and then compute PI. These systems eliminated a lot of the subjectivity that occurs with a rater (person).

The basic steps to compute PI are:

1) Outline the Profile Trace. The purpose of outlining the trace was to “average” out spikes and minor deviations caused by debris on roadway, texture, etc.

2) Position Blanking Band. The blanking band is placed over the profile trace so that it blanks out as much of the profile as possible. The placement of the blanking band should be such that the excursions or scallops are evenly distributed above and below the blanking band. A blanking band ranges from 0.2 in (5 mm) wide to 0.0 in.

3) Determine Profile Index. Excursions which extend in a specified height above the blanking band for a specified horizontal distance will be recorded on the profile. The sum of the recorded heights within a given segment will be the Profile Index (PI) for that segment. The profile index is expressed in terms of in per mi.

#### *4.3.2 SOFTWARE*

STE investigated two available freeware: RoadRuf and ProVAL. RoadRuf was developed by UMTRI with funding from FHWA *(12)*. RoadRuf was part of a research project called "Interpretation of Road Roughness Profile Data" and was completed in 1996 *(13)*. The algorithms used in the software are identical to those published by the UMTRI researchers in a variety of FHWA reports, TRB papers, and World Bank technical reports.

RoadRuf was developed for computers equipped with Windows 3.1, 95, or NT. The environment which the user sees is called a Simulated Graphical User Interface (SGUI). There have been no updates since 1997.

RoadRuf has an integrated set of computer tools for interpreting longitudinal road roughness profile data. RoadRuf has features such as:

- Calculating of IRI and RN of many profiles in a single batch run,
- Generating of standard plots,
- Applying moving average filters to profile plots,
- Overlaying function of plots of repeat measurements of the same road,
- Viewing wavelength content of pavement using power spectral density (PSD) functions, and
- Calculating arbitrary profile indices by specifying their sensitivity to wave number.

The format required for the profile data is ERD format. Some equipment manufacturers including ICC can export their data in ERD format. Initially, MDT was unable to export data into ERD format, but worked diligently with ICC to resolve this issue. STE requested and obtained MDT ERD formatted data to try the freeware.

ProVAL is short for "Pavement Profile Viewer and Analyzer". ProVAL is currently being developed for the FHWA by The Transtec Group located in Austin, Texas under the DTFH61-01-P-00159 and DTFH61-03-P-00344 contracts to provide a means to view and analyze profile data efficiently and robustly *(14,15)*.

ProVAL was developed for computers operating with Windows 98, NT, 2000, or XP Professional, and a recommended 1 GB processor. ProVAL features a profile data viewer and several common profile data analyses (e.g., IRI, RN, PI, PSD, Butterworth filtering, Profilograph simulation, Rolling straightedge simulation, etc.).

It also imports three profile data formats: the industry standard ERD format, the Texas DOT format, and the KJ Law profiler format. Other formats may be added to the import functionality of the software as manufacturers join with the software developers. A new standard profile format called PPF was also created.

ProVAL is currently being updated. ProVAL 2.5 was released in spring 2005. This version intended to incorporate event markers, linear distance adjustment, continuous roughness reports, TX DOT localized roughness identification, and a localized roughness algorithm with a grinder simulation called *Bumpfinder*.

## 4.4 STE ANALYSIS OF SOFTWARE & INDICES

As part of the kick-off meeting action items, STE requested ERD format data from MDT to evaluate different software and compare with MDT's current process. During September 2004, MDT provided data for four sites as shown in Table 4.4.

*Table 4.4. Provided Profile Data.*

| Class | Type | Project | Project Number | Control Number | Direction |
|---|---|---|---|---|---|
| Class I | Reconstruction | Silver Star (NB & SB) | STPP 29-1(31)50 | 1022 | Both |
| Class I | Reconstruction | Valier-West | STPP 44-1(11)0 | 1291 | Both |
| Class I | Reconstruction | Plentywood-West | STPP 22-2(15)30 | 1393 | Both |
| Class I | Reconstruction | Ringling-North | STPP 59-2(9)49 | 1513 | Both |

### *4.4.1 ROADRUF*

As mentioned before, RoadRuf was developed by UMTRI in 1996. RoadRuf was developed for computers equipped with Windows 3.1, 95, or NT. The environment which the user sees is called a Simulated Graphical User Interface (SGUI).

RoadRuf is an older software with its last update in 1997. There are issues installing on newer computers with operating systems of Windows 2000 or higher. Its interface still has DOS-like attributes, which MDT does not desire.

STE had problems loading different files and plotting results. It was also not possible to subsection the entire profile into desired sections. Although, RoadRuf can calculate IRI, RN, and other indices of many profiles in a single batch, it would not be efficient in current and future MDT profiling operations without major modifications.

### *4.4.2 PROVAL 2.5*

ProVAL is a more recently developed software. FHWA's goal is to enhance ProVAL to provide a tool to view and analyze profile data efficiently by all interested parties (i.e., agencies, contractors, etc.).

The latest version of ProVAL at the time of this evaluation was ProVAL 2.5, which was going through beta testing during the course of this project. STE requested from FHWA and was given the opportunity to be a beta tester for the software during this project. STE was one of the twenty-three reviewers of the beta version software, who provided input to the software developer and FHWA.

STE also attended a ProVAL 2.5 workshop held during the Road Profilers User Group (RPUG) Conference in Stateline, NV on October 24-27, 2004. The workshop provided hands on training with ProVAL 2.5 and an opportunity to discuss profiling topics with peers.

The software operates with current computers and current operating systems. It allows the use of different formats. ProVAL 2.5 not only performs common analyses like IRI, RN, PI, PSD, Butterworth filtering, profilograph simulation, and Rolling straightedge simulation, it also allows the placement of event markers (i.e., a mark in the profile data indicating start and end of smoothness evaluation area). The yet to be released software also incorporates linear distance adjustment, continuous roughness reports, TX DOT localized roughness identification, and localized roughness algorithm, Bumpfinder, with grinder simulation, which will be discussed in the following sections.

### *4.4.3 IRI ANALYSIS*

STE evaluated a series of profile data sets that were provided by MDT. STE analyzed and compared the data outputs from ProVAL 2.5 with the hard copy outputs of the ICC profiler software (RP090L V3.16).

First, the hard copy output was evaluated. All the data sets evaluated used zero (0) as the start point for data collection. However, the units of profile data collection were not consistent. Control # 1022 was collected in U.S. Customary units while Control # 1291, 1393 and 1513 were in SI units.

Another observation was that some sections appeared to be edited. These sections were likely edited because they were excluded areas (e.g., possibly excluded section like bridge approaches, acceleration lanes, etc.). However, the hardcopies did not indicate what part of a given section was edited. It simply placed an asterisk next to the number indicating an edit. Because STE did not know what was edited, it did not alter the section data for this analysis.

The hard copy output showed the results for each wheel path in intervals of 1056 feet or 300 m. The length of MDT smoothness evaluation sections is 1056 feet (0.2 miles). Although 300 m (984 feet) is close to 1056 feet, it is not truly a smoothness evaluation section as defined in the specification. This is an illustration of an issue with inconsistent units.

Another hard copy observation was that the DMI was not always positive. In the profiler software, one can define what direction is positive and what direction is negative. Control # 1393 WB used a negative value so its stations are all negative. This is beneficial if one is using stations as the reference, but using stations has not been advantageous in finding bumps or dips in profile data.

STE recommends selecting one system of units (e.g., U.S. Customary), selecting one method of section identification (Start at 0 feet) and one direction of travel (All directions are positive). This will aid in consistency for operators as well as make it more consistent for engineers trying to locate sections with profile defects.

STE uploaded the ERD formatted data into ProVAL 2.5 for each data set. STE attempted to match sections identified in the hard copy output. Although ProVAL 2.5 allows the user to create sections, it can be time consuming if there are a lot of unique length sections caused by excluded areas.

The comparison of section IRI's were close in all data sets. The comparison of wheel path IRI's, total IRI's, and Mean IRI's were close in all data sets as well (Table 4.5). Control #1513 had the largest difference of 6-7 in/mi (0.09-0.11 m/km) in the right wheel path. This was likely due to editing of data at start of section.

*Table 4.5. IRI of ICC Software versus ProVAL 2.5.*

| | | LWP IRI (in/ mi) [m/km] | | RWP IRI (in/ mi) [m/km] | | Mean IRI (in/ mi) [m/km] | |
|---|---|---|---|---|---|---|---|
| Control Number | Direction | ICC Software | ProVAL 2.5 | ICC Software | ProVAL 2.5 | ICC Software | ProVAL 2.5 |
| 1022 | NB | 65 [1.03] | 65 [1.03] | 54 [0.85] | 54 [0.85] | 60 [0.95] | 59 [0.93] |
| 1022 | SB | 62 [0.98] | 62 [0.98] | 54 [0.85] | 54 [0.85] | 58 [0.92] | 58 [0.92] |
| 1291 | EB | 37 [0.58] | 37 [0.58] | 38 [0.60] | 39 [0.62] | 38 [0.60] | 38 [0.60] |
| 1291 | WB | 39 [0.62] | 40 [0.63] | 39 [0.62] | 39 [0.62] | 39 [0.62] | 40 [0.63] |
| 1393 | EB | 50 [0.79] | 50 [0.79] | 49 [0.77] | 48 [0.76] | 49 [0.77] | 49 [0.77] |
| 1393 | WB | 47 [0.74] | 47 [0.74] | 48 [0.76] | 48 [0.76] | 48 [0.76] | 47 [0.74] |
| 1513 | NB | 44 [0.69] | 46 [0.73] | 45 [0.71] | 51 [0.80] | 44 [0.69] | 48 [0.76] |
| 1513 | SB | 43 [0.68] | 46 [0.73] | 44 [0.69] | 51 [0.80] | 44 [0.69] | 49 [0.77] |

The results of this analysis show that ProVAL 2.5 does calculate IRI in the same manner as the ICC profiler software (i.e., using same algorithms) and that ProVAL 2.5 is an alternative to the ICC profiler software.

### *4.4.4 BUMP IDENTIFICATION ANALYSIS*

ProVAL 2.5 incorporates other features like event marker insertion, linear distance adjustment, continuous roughness reports, TX DOT localized roughness identification, and localized roughness algorithm, Bumpfinder, with grinder simulation.

As shown in literature review as well as the survey, bump identification is a concern for all agencies including MDT. Using a non-contact type instrument to locate bumps is difficult. Although a profiler collects an enormous amount of data, the data goes through various processes (i.e., filtering) that can diminish the accuracy of finding a "bump" (e.g., it can reduce the height of the bump).

STE evaluated the Profilograph Simulation, the Bumpfinder and Grinding Simulation, and the Localized Roughness (TEX-1001-S) Method in ProVAL 2.5 for their bump finding potential.

#### 4.4.4.1 Profilograph Simulation

The Profilograph Simulation tries to simulate a profilograph. This simulation was evaluated for its potential of replacing MDT's current method. MDT's current method uses ProScan via the ICC profiler software.

The Profilograph Simulation in ProVAL 2.5 allows the user to input the blanking band, scallop width, scallop rounding increment, the type of profilograph, the number of wheels, and the wheel offsets.

The next step is to run the Profilograph simulation filter by pressing the Run Filter button. After the filter has been applied, the simulated California Profilograph trace appears on the screen, as shown in Figure 4.6, with automatic segments set at 528 foot (160.9 m) increments. If additional or fewer blanking band segments are desired, press the Segments button. A window will be shown allowing one to add and remove segments. This is one of the drawbacks of using the Profilograph Simulation. In MDT's case, segments of 25 feet (7.62 m) are desired for bump finding, which means the user would have to input manually 25 feet (7.62 m) segments. This would be very time consuming. The ProVAL 2.5 developers are considering allowing the user to designate the automatic segments prior to running the filter but it is not currently operational.

Once the appropriate blanking band segments have been defined, the Analyze button is pressed to perform the analysis and compute the California Profilograph Index. For each segment, and for each profile selected in the Profiles screen, the Raw PI and the Rounded PI are calculated. This analysis can only be performed on one file at a time. In Figure 4.7, the Raw PI and Rounded PI are shown in the middle of the window. Currently, ProVAL 2.5 does not have an easy way of copying values into a spreadsheet. The user can only save the output in HTML format.

ProVAL 2.5 can produce a PI for 25 feet (7.62 m) segments, but it is very time consuming when evaluating miles of pavement. Additionally, the value obtained would not truly represent a "bump" or "dip" since the simulation is calculating PI and not identifying defect locations specified by the user such as the 0.4 inch (10 mm) in 25 feet (7.62 m).

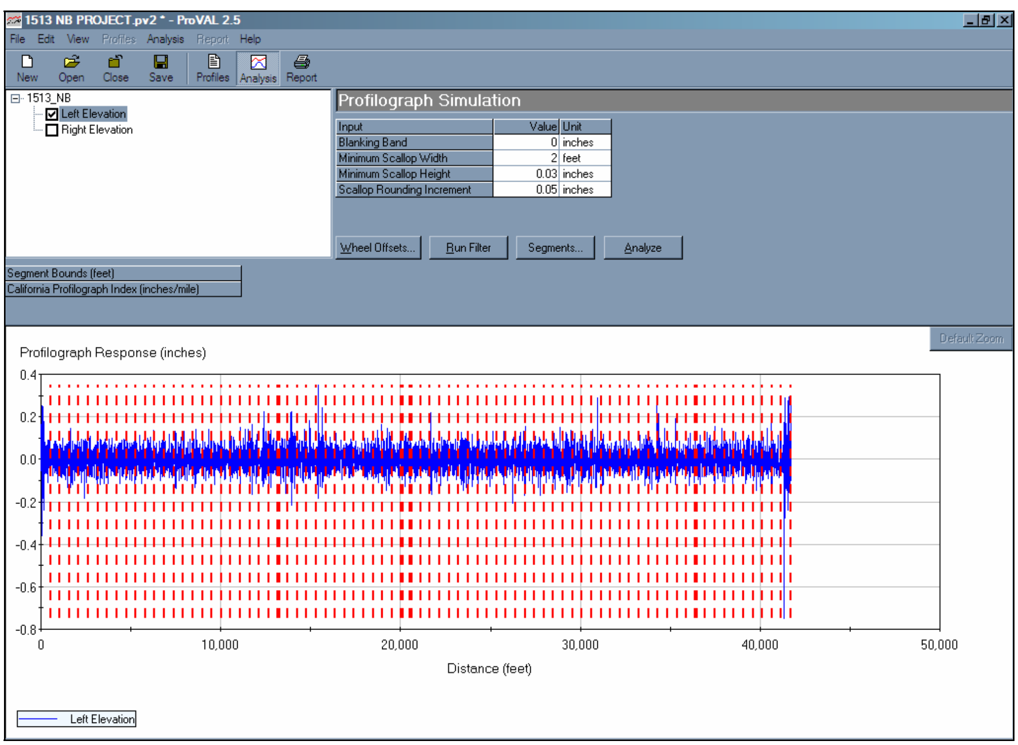


*Figure 4.6. Profilograph Simulation Run Filter.*

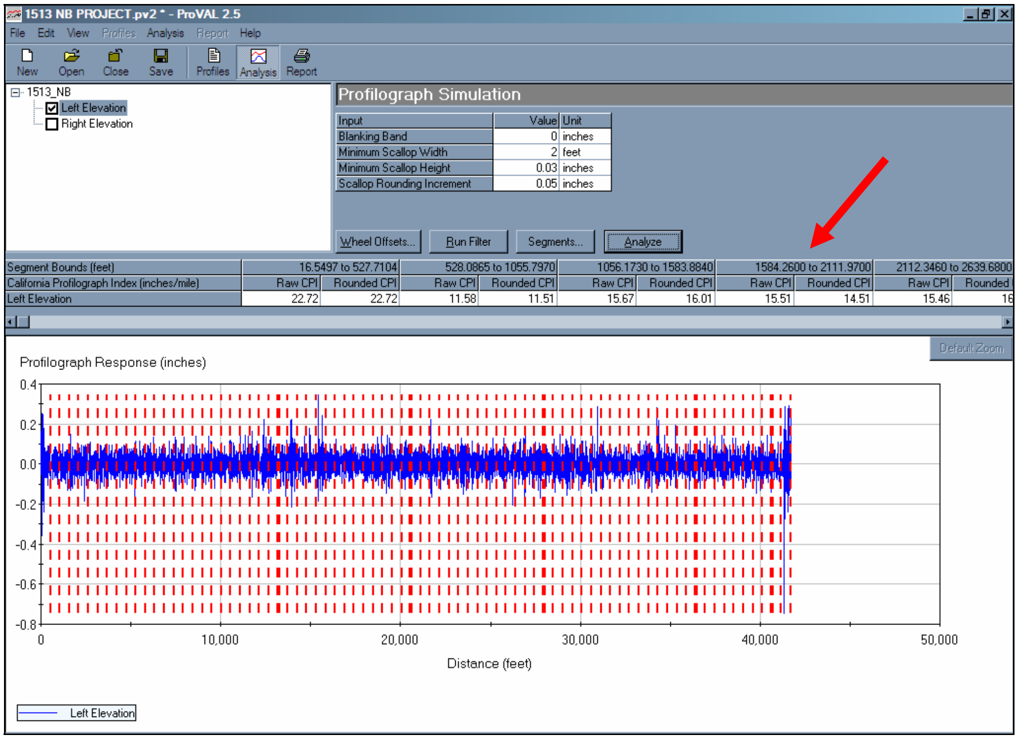

*Figure 4.7. Profilograph Simulation PI Calculation for Segments.*

#### 4.4.4.2 Bumpfinder and Grinding Simulation

The Bumpfinder and Grinding Simulation was one of the major developments in ProVAL 2.5. This section is primarily taken from ProVAL User's Guide, Version 2.50 (pg. 16-26) *(15).* The Bumpfinder and Grinding Simulation can be used to optimize grinding strategies. It can determine the "out-of-spec" locations and recommend must-grind locations. It provides flexible, "user-defined" grinding strategies. A comprehensive report can also be generated that includes ride quality reports before and after grinding.

The Bumpfinder and Grinding Simulation has five screens:

- Input: Location where inputs are inserted that are necessary to run the analysis.
- Analysis: Displays the ride quality specification results and "hot-spots".
- Grinding: Location where inputs are inserted that are necessary to setup the grinding simulation.
- Grinding Results: Shows the grinding results.
- Warnings: Warns users about possible problems with the profile data.

The first two screens are for the ride quality report as shown in Figures 4.8 and 4.9.

In the input window, the user can select a desired Ride Quality Index (e.g., IRI, RN or HRI) for analysis. A "Ride Quality Threshold" and continuous interval can also be inputted to identify hot spot or out-of-spec sections in a continuous roughness report. The Ride Quality Threshold would be similar to a bump criterion. For analysis purposes, STE tried several values of IRI equal to 65 in/mi (1.03 m/km), 90 in/mi (1.42 m/km), and 95 in/mi (1.50 m/km). The value discussed in the AASHTO provisional standard is an IRI of 95 in/mi (1.50 m/km) *(9)*.  There is not an abundance of literature discussing bump identification as a factor of IRI.  For agencies that have utilized bump specification in the past, there is no legacy knowledge of an IRI threshold.

The "Fixed Interval" input (normally 528 feet (160.9 m) can be used to produce a fixed interval roughness report.  The "Profile Selection and Adjustment" Inputs are related to profile selection, linear distance adjustment (i.e., DMI), and resetting start/end points for the analysis.  Users may use the File drop-down box to select a single profile data (all imported profiles from the profile viewer window are available) for the analysis.

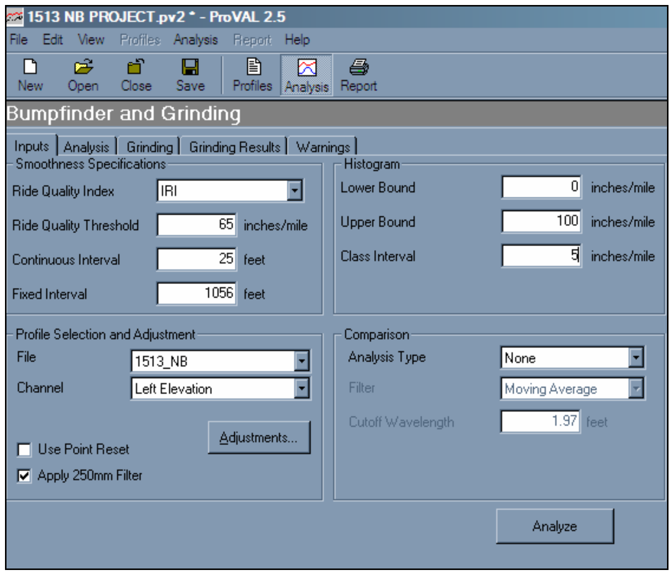


*Figure 4.8.  Bumpfinder Input Window Smoothness Specification Inputs.*

The Histogram Inputs are used to produce a histogram from the fixed interval roughness report.  Users can specify the Upper Bound, Lower Bound, and Class Interval.  The Upper Bound and Lower Bound are used to limit the reporting range.  The Class Interval will be used as the "step" to count frequencies of occurrence (i.e., sections).  The Ride Quality Threshold value from the Smoothness Specification Inputs will be used to compute the percentage of pavement sections that are out-of-spec.

The Comparison Inputs allows the user to compare the IRI versus Raw Profile, Profilograph, or Rolling Straightedge.  ProVAL will display the corresponding trace side-by-side with the roughness report. Otherwise, the simulation will not be performed and no side-by-side comparison will be produced.

The Analysis window shows the ride quality spec report along with one or two plots.  There are three tabular reports.  On top left, Continuous Report Defective Segments shows the sections that are over the threshold value and their maximum values within these sections.  Immediately beneath the previous report is the histogram report that contains the histogram from the continuous roughness analysis.  This histogram defines the percentage of the job that falls within each roughness range of interest.  These percentages may be weighed against an incentive pay schedule to calculate the overall bonus or penalty.  A percentage of Pavement Out-of-Spec is also reported to indicate those that are over the Ride Quality Threshold.

Finally, the last table at the bottom is the Fixed Report, which shows the roughness values for all fixed-length sections.

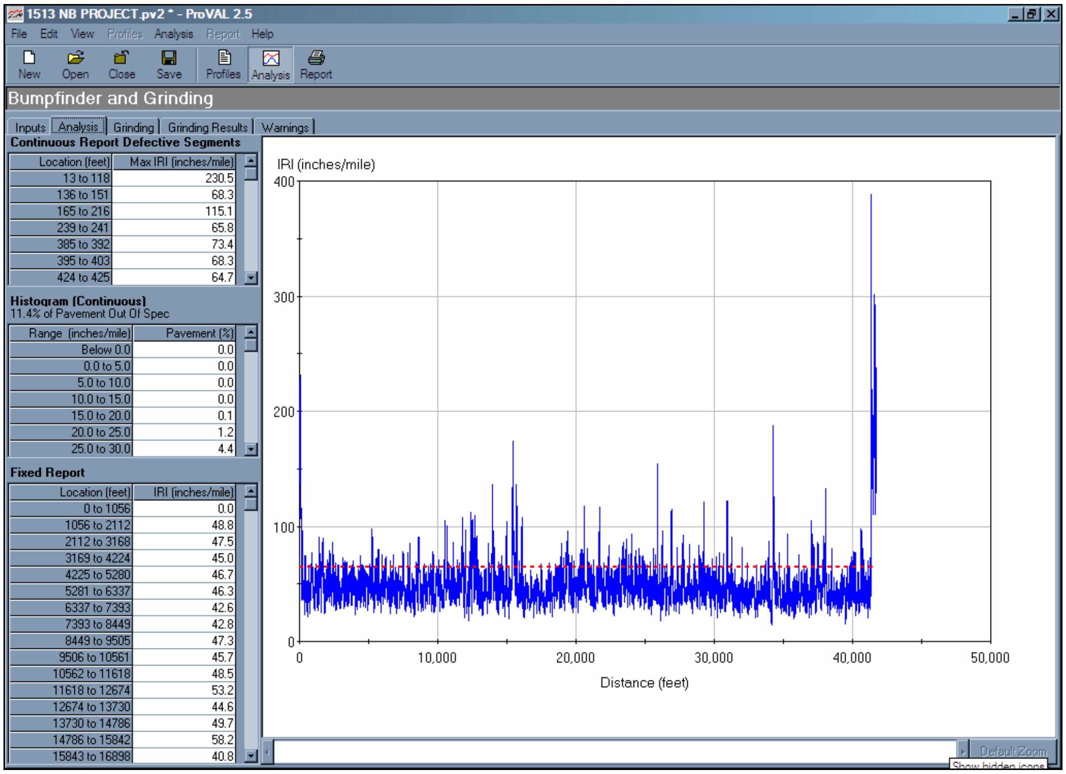


*Figure 4.9. Bumpfinder Analysis Window.*

The third and fourth screens are for grinding simulation. The Grinding Window shown in Figure 4.10 allows users to define the grinder parameters to be simulated. The user can select a grinder type from the Grinder Type drop down box. The types of grinders are User-defined, 18-foot Wheelbase, and 25-foot Wheelbase. For the User-defined grinder, the additional inputs needed are Head Position, Wheelbase, Tandem Spread, and Short Wavelength Cutoff. For 18-foot Wheelbase and 25-foot Wheelbase, the above inputs are fixed and not editable.

The Head Position is defined as the front tandem center to the grinding head divided by the wheelbase. The Wheelbase is distance between tandem centers. The Tandem Spread is self-explained. The Short Wavelength Cutoff is used in a low-pass filter (currently, moving average) during grinding simulation. For any grinder selection, the Maximum Grinding Depth should be user-defined to limit the maximum depth that may be taken in a given pass.

The Grinding Locations and the Selected Grinding Location can be used to define any grinding sections and grinding setups (starting and end points, head height, and directions). Use Defaults button provides users a list of grinding locations. One Grind is used to define a single grind location to cover the entire length.

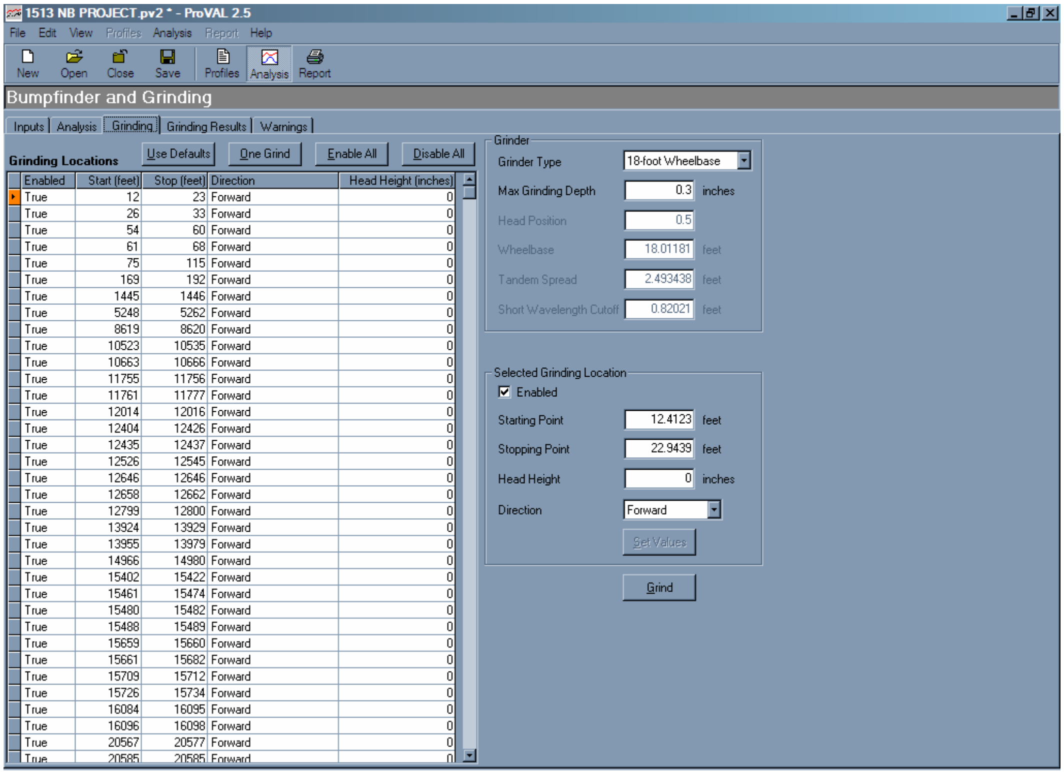


*Figure 4.10. Bumpfinder Grinding Window.*

For each Selected Grinding Location, users may decide whether to grind it or not by selecting or unselecting the Enable checkbox. Users can also define the Start and End Points, Head Height of the grinder, and Direction. There are several options for the Direction definition: forward, reverse, forward-forward, reverse-reverse, forward-then-reverse, and reverse-then-forward (the first two is for one-pass grinding and rest are for two-pass grinding). Users may cycle through those options to achieve the best grinding effects.

The Grinding Results Window as shown in Figure 4.11 presents a few tables and plots of the user defined grinding. The Continuous Report Defective Segment report, Histogram report, and Fixed Report are similar to those in the Ride Quality Specification Analysis except the results here are for those after-grinding. The plot shows the previous IRI plot and the IRI plot after grinding.

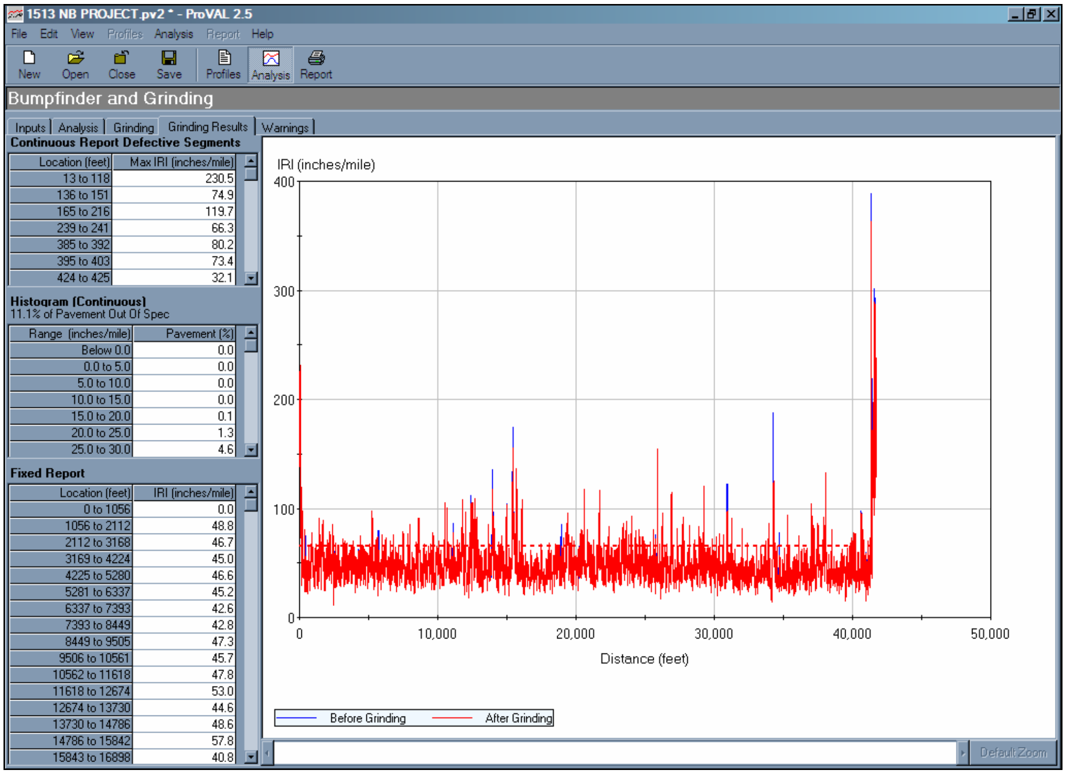


*Figure 4.11. Bumpfinder Grinding Results Window.*

The last window is the Warnings window, which is used to check whether there are potential errors in the profile data or during the analysis. A table is generated that shows the channel of profile data, the locations, and the warning types as seen in Figure 4.12. The warning types consist of the following: Spikes, Bump or Dip, Extreme Roughness, and Deep Grinding.

STE specifically evaluated Control # 5110, Project STPP 14-1(17)11 located near Deep Creek Canyon. Using an IRI threshold of 95 in/mi (1.50 m/km), 22% of the pavement failed the tolerance. The hard copy that MDT provided STE shows that there were only 54 defect locations in the EB direction. There was no direct comparison between the Bumpfinder and Grinding Simulation and the MDT results.

The Bumpfinder and Grinding Simulation appears to be powerful and allows the engineers to strategize profile corrections but there are drawbacks. MDT would have to define an IRI threshold, which may or may not identify a “bump” or “dip”. Also, ProVAL 2.5 is still being evaluated and as with any new software there are still issues (e.g., loading files, processing files, and reporting results).

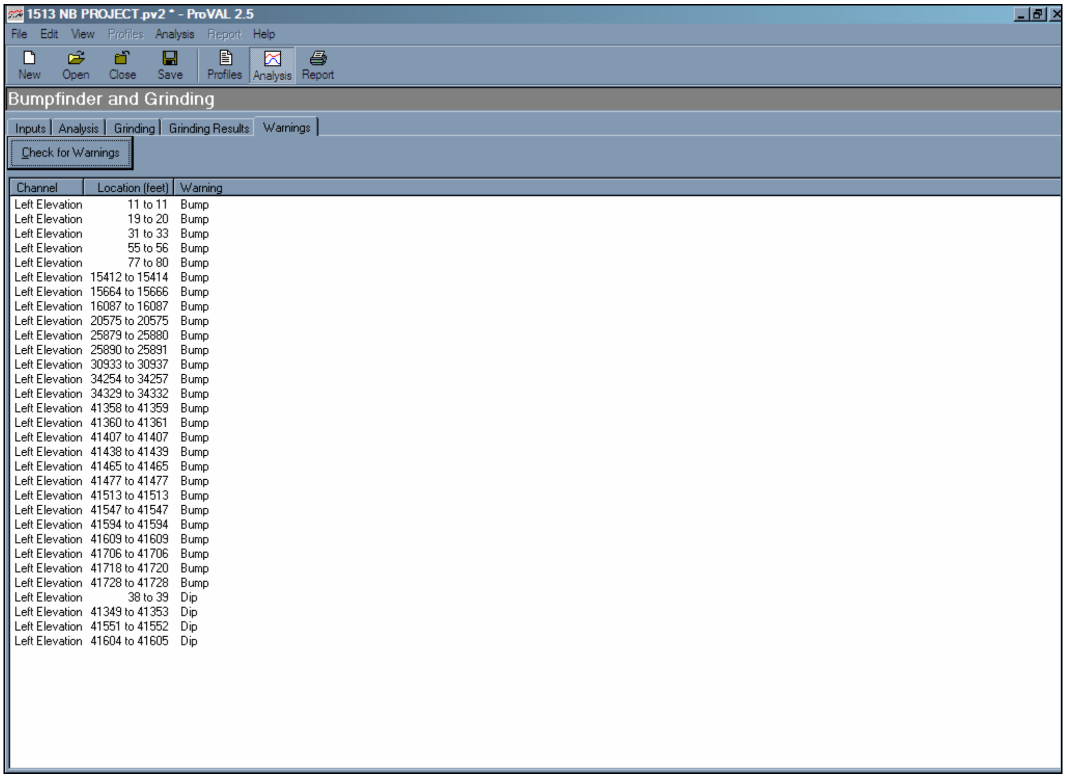


*Figure 4.12. Bumpfinder Warnings Window.*

#### 4.4.4.3 Localized Roughness (TEX-1001-S) Method

This method is discussed in the AASHTO PP 51-03 Pavement Ride Quality When Measured Using Inertial Profiling Systems as well as the TX DOT Specification 1001-S. The analysis procedures are as follows:

- Average each elevation point from the two longitudinal profiles (left and right wheel paths) from a travel lane to produce a single averaged wheel path profile.
- The single averaged wheel path profile will then be placed on a 25-foot (7.62 m), centered-moving average filter.
- The difference between the average wheel path profile and the 25 foot (7.62 m) moving average filtered profile for every profile point is determined.
- Deviations greater than 0.15 inches (3.81 mm) are considered a detected area of localized roughness. Positive deviations are considered as "bumps" and negative ones as "dips".

In ProVAL 2.5, Localized Roughness (TEX-1001-S) is selected in the Analysis menu. The user has to select both left and right channels (wheel paths) of a single profile data in order to perform this analysis.

The Sliding Base Length and Deviation Threshold can be changed by the user but the input values of 25 feet (7.62 m) and 0.15 inches (3.81 mm) is defined in the Texas specification. ProVAL reports the "bumps" and "dips" identified with this method in a table as well as a plot. The table shows the locations/sections where the deviation has exceeded the threshold as well as the deviation value at the midpoint of each identified section.

There are two plots either Moving Average or Deviation. The Moving Average option (Figure 4.13) shows the single average profile and its moving average, while the Deviation option (Figure 4.14) allows the user view the deviation from the threshold value.

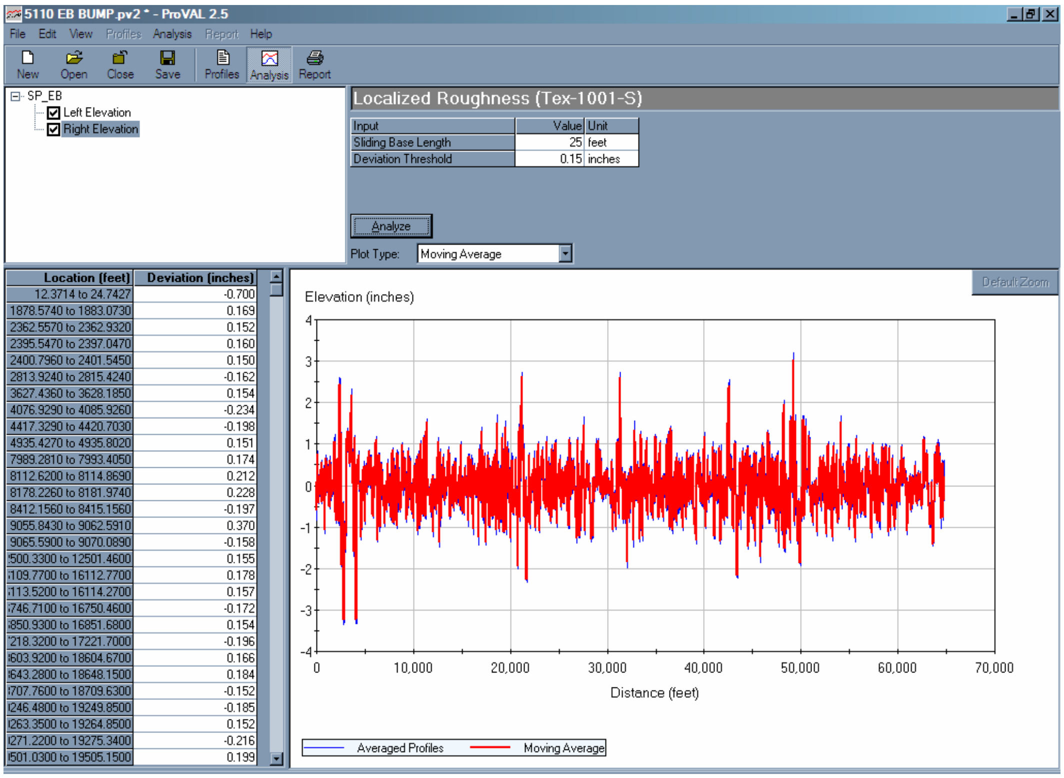


*Figure 4.13. Localized Roughness (TEX-1001-S) Window with Moving Average Plot.*

STE specifically evaluated Control # 5110, Project STPP 14-1(17)11 located near Deep Creek Canyon. The hard copy that MDT provided STE shows that there were only 54 defect locations in the EB direction. Also, the data set used stationing as the reference rather than zero (0) as the start location. The data set was also in SI units. The Localized Roughness (TEX-1001-S) Method identified 76 locations. The locations were similar to the defect locations identified in the ProScan software. Direct comparison of values due to unit conversion and referencing issues was not performed.

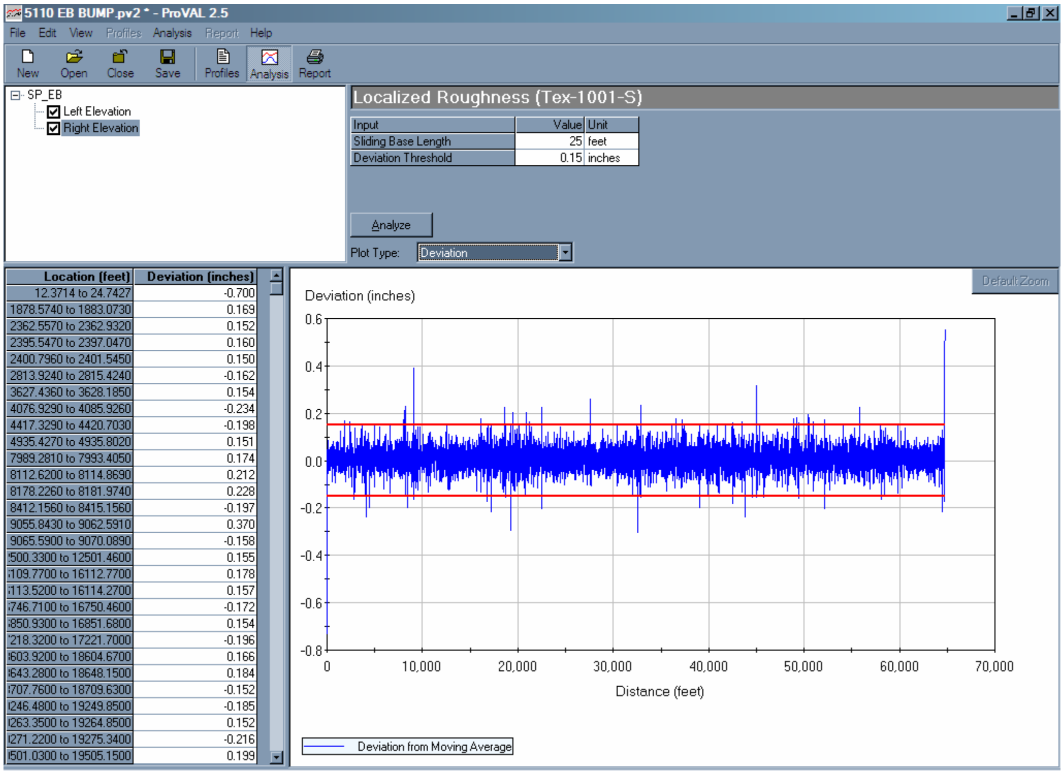


*Figure 4.14. Localized Roughness (TEX-1001-S) Window with Deviation Plot.*

## 4.5 AASHTO PROVISIONAL STANDARDS

STE has reviewed AASHTO provisional standards developed by FHWA and an Expert Task Group (ETG) namely: MP11-3 Profiler Equipment Specification *(5)*, PP 37-04 Determination of IRI to Quantify Roughness of Pavements *(6)*, PP49-03 Profiler Certification Program *(7)*, PP50-30 Smoothness Measurement Test Methods *(8)*, and PP51-03 Pavement Smoothness Specification *(9)*.

### *4.5.1 AASHTO MP 11-03 INERTIAL PROFILER*

This specification defines the attributes of an inertial profiler *(5)*. It defines some of the terminology used in this area such as accelerometer. It discusses some of the general system requirements such as speed, triggering system, etc. It discusses the equipment that makes up the profiler such as accelerometer, printer, DMI, etc.

This specification would be useful when an agency is requesting a bid on a new profiling system. AASHTO MP 11-03 recommendations have been incorporated in the Profiler Operations Manual that STE developed for MDT.

### *4.5.2 AASHTO PP 37-04 DETERMINATION OF IRI TO QUANTIFY ROUGHNESS OF PAVEMENTS*

This specification describes a method for estimating roughness for a pavement section using the IRI statistic *(6)*. This specification also recognizes the need for a QC/QA plan and proposes guidelines for

QC/QA development. Finally, the specification references ASTM E950, which is the standard test methodology for measuring the longitudinal profile of traveled surfaces with an accelerometer established inertial profiling reference.

This specification is relatively short. It indicates that agencies that are collecting ride data (to determine IRI to quantify roughness of pavements) are required to develop a satisfactory QC/QA plan with at least a section on qualification and training records of individuals profiling, records on accuracy and calibration of equipment, and records on periodic and ongoing QC/QA. This is covered in the QC/QA Plan and in the Profiler Operations Manual developed by STE.

### *4.5.3 AASHTO PP 49-03 CERTIFICATION OF INERTIAL PROFILING SYSTEMS*

This specification describes minimum performance requirements for inertial profilers to be used for smoothness acceptance by an agency *(7)*. It discusses equipment calibration verification, operator qualification, and equipment certification.

Operator qualification is discussed in STE's draft QC/QA plan. There currently is no national training available.

This specification looks at static, dynamic, bounce, and DMI tests. Equipment calibration and verification is covered in the Profiler Operations Manual. Equipment certification is similar to the FHWA LTPP profiler rodeos. There are two different types of test surfaces (smooth and medium roughness) of at least 528 ft (160.9 m). Equipment repeatability is evaluated by looking at the standard deviations of ten repeat measurements. Equipment accuracy is also evaluated. A benchmark or "reference" profile is established using rod and level, dipstick, or some other device that provides unfiltered profiles. A point to point comparison is performed. The point to point differences must be within a certain value (e.g., 20 mils). Finally, there is a verification of computed ride statistics.

AASHTO recommends looking at the ten repeat measurements and computed IRI. The standard deviation of the IRI is computed for each profile trace. The standard deviation should not exceed a certain value (e.g., 3 inch per mile). It is STE's opinion that it will take a large amount of resources to organize a rodeo type event. This specification may be more appropriate for an agency that does not collect the profile data itself (i.e., where the contractor collects the data).

### *4.5.4 AASHTO PP 50-03 OPERATING INERTIAL PROFILERS AND EVALUATING PAVEMENT PROFILES*

This specification describes the procedure for operating and verifying the calibration of an inertial profiler *(8)*. It is recommended for QC testing and network level data collection. It also provides evaluation procedures that are generated and a methodology for resolving disputes arising from suspect profiler output.

Equipment verifications for horizontal and vertical measurements are discussed as well as procedures for verifying horizontal and vertical calibration, bounce tests, and calibration log. This specification also presents measuring pavement profile procedures. This is all described in the Profiler Operations Manual.

The specification indicates that the standard deviation for multiple runs on the same 0.1 mile (0.16 km) section using the same equipment has been determined to be 2%. Therefore the results from two runs using the same equipment should be considered suspect if they differ by more than 5.7% of their mean. The bias of this has not been determined. STE has incorporated these tolerances in the revised MT-422.

#### *4.5.5 AASHTO PP 51-03 PAVEMENT RIDE QUALITY WHEN MEASURED USING INERTIAL PROFILING SYSTEMS*

This specification is intended to be used as an example specification for Owner-Agencies to use when developing a specification *(9)*. It provides specific language when requiring the measurement and evaluation of ride quality and compliance using inertial profiling systems.

It does define localized roughness as areas of localized roughness identified via a 25 ft (7.62 m) moving average filter. The difference between the moving average and every profile point is determined and deviations greater than 0.15 in (3.81 mm) are considered a detected area of localized roughness. This is essentially the Texas Specification. It also looks at a test procedure using a straightedge and an inertial profiling system. Work methods for transverse and longitudinal profiles are described. QC/QA testing and referee testing are discussed. If independent testing results produce an IRI that differs from the obtained profile by more than 6 in per mile (0.09 m per km), then the agency/contractor should attempt to resolve the differences. This provisional standard also briefly discusses pay adjustment factor schedules and is made on 0.1 mi (0.16 km) sections.

This provisional standard also briefly discusses deficiencies and corrective work. It specifies that corrective work will be at the contractor's expense. It indicates that any 0.1 mi (0.16 km) section having an average IRI of over 95 in/mi (1.50 m/km) should be corrected to an IRI of 65 in/mi (1.03 m/km) or less. STE has already discussed the need to set a maximum IRI threshold above which a corrective action needs to be undertaken by the contractor similar to this provisional standard.

### 4.6 EXCLUSIONS & CONSTRAINTS

During the literature search, STE investigated the following issues regarding excluded pavements and constraints to testing:

- Investigate constraints of data collection along horizontal curves (i.e., 900 ft (274.32 m) radius taken from vendor operation manual).
- Investigate whether 0.2 mile (0.32 km) distance is enough for acceleration of profiler for climbing and passing lanes.
- Should bump criterion be implemented for areas 150 feet (45.72 m) adjacent to bridge decks?

#### *4.6.1 HORIZONTAL CURVES*

STE studied the other agencies' ride specifications to obtain information on the most currently followed procedure. Ten agencies (i.e., California, District of Columbia, Idaho, Kansas, Minnesota, Mississippi, Nebraska, Nevada, Oregon, and Utah) have discussed horizontal curve data collection constraints in their ride specifications. Six agencies indicated a curvature of radius less than 1000 ft (304.8 m). One agency indicated a curvature of radius less than 984 ft (300 m). One agency indicated a curvature of radius less than 950 ft (289.56 m). One agency indicated a curvature of radius less than 900 ft (274.32 m). These values are close to the 900 ft (274.32 m) constraint currently used by MDT. STE recommends that MDT continues using the 900 ft (274.32 m) curvature of radius as the constraint along horizontal curves.

#### *4.6.2 CLIMBING & PASSING LANES*

STE did not locate clear information from the other specifications directly discussing what the run-up (acceleration) distance should be for testing climbing and passing lanes. Although, there were two agencies that did exclude some climbing lanes: Minnesota excludes climbing lanes and Virginia excludes truck climbing lanes less than 0.5 miles (0.80 km) in length. This is a question that is more specifically about a high speed profiler and the amount of road it needs to get to testing speed. STE's recommendation as described in the Profiler Operations Manual is that the profiler should be up to speed 500 ft (152.4 m) prior to the start of the test section. In a 0.2 mi (0.32 km) segment, this leaves only 0.1 mi (0.16 km) to accelerate from standstill to 50 mph (80 km/h) or some desired lower speed greater than 10 mph (16 km/h). STE recommends the following criterion: If possible, a profile run should have 0.75 mile (1.2 km) of run-up distance before testing any roadway, whether it is a climbing lane, passing lane or ramp.

#### *4.6.3 AREAS ADJACENT TO BRIDGE DECKS*

Bridge decks, panels, and approach slabs are discussed in most of the other specifications. These are usually excluded from pavement smoothness evaluation except when the bridge is overlaid. STE recommends that if the bridge was not overlaid as part of the project, it should be excluded.

A review of other agencies' specifications (i.e., Arizona, Georgia, Idaho, Iowa, Louisiana, Maine, Mississippi, Nebraska, Nevada, Oregon, Texas, and Utah) suggests that the average distance from the bridge (i.e., expansion joint or slab) is approximately 80 feet. AASHTO suggests a 100 feet (30.48 m) exclusion area (for penalties) from the bridge deck. The profiler should have no issues collecting the data all the way to and from the bridge deck. The issue is the possibility of localized roughness due to construction constraints in the vicinity of a bridge deck. For any bridge structure and/or approach slabs that have not been overlaid as part of the project, STE recommends measuring pavement sections up to 50 feet (15.24 m) from the structure and then resuming measurement 50 feet (15.24 m) past the structure. This applies to incentive and disincentive payments.

Regardless of bridge section exclusion from the pavement smoothness evaluation, it is sometimes evaluated for bumps and dips. STE has identified at least 11 agencies that use a bump criteria for excluded bridge sections. STE recommends the use of the same bump criteria used in the ride specification for excluded bridge deck sections.

# 5.0 TASK C. CONDUCT A STATE OF THE PRACTICE SURVEY

## 5.1 BACKGROUND

As part of this task, STE developed a state of practice survey to be distributed to other agencies with the intent of learning about their current ride specification and practices. STE's developed draft survey was first reviewed by the MDT project panel. The project panel suggested that the survey be narrowed to only questions related to ride specification for asphalt concrete pavements. STE finalized the survey based on the feedback received from the panel and distributed the survey to all 49 states (besides Montana). STE contacted every agency by phone to describe the purpose of the survey followed by an email containing the survey itself. A total of 32 agencies responded to the survey.

Appendix A contains a copy of the survey sent to the agencies. The survey was divided into the following sections: Specification, Equipment, Incentive / Disincentive, QC / QA, and Programs. Appendix B contains the results of the survey in a tabulated format.

The remainder of Section 5 presents the results of the survey.

## 5.2 INITIAL RIDE QUALITY SPECIFICATION

Figure 5.1 shows that over 90% of agencies have some form of initial ride quality specification.

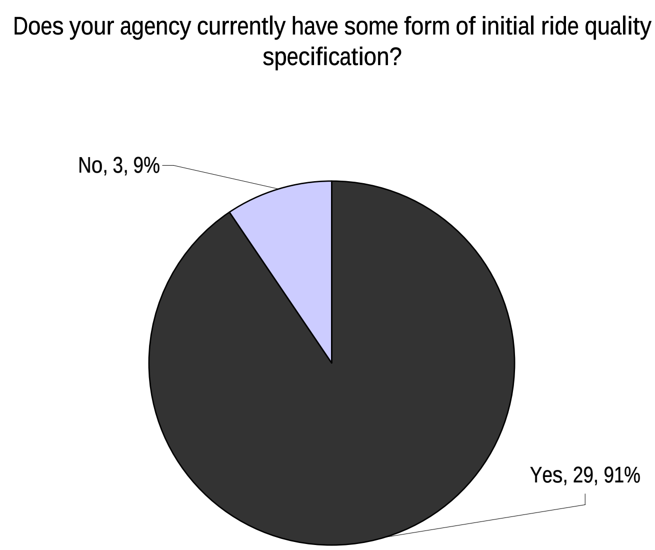


*Figure 5.1. Initial Ride Quality Specification.*

## 5.3 COLLECTION OF ACCEPTANCE PROFILE DATA

In Montana, MDT collects all profile data for acceptance. In many other agencies, the contractors collect the data and in some both the agency and the contractor are involved in the data collection efforts. One observation is that not all agencies shown in Figure 5.2 use high speed inertial profilers, which is the most expensive data collection equipment available. Many contractors simply do not have access to inertial profiler equipment.

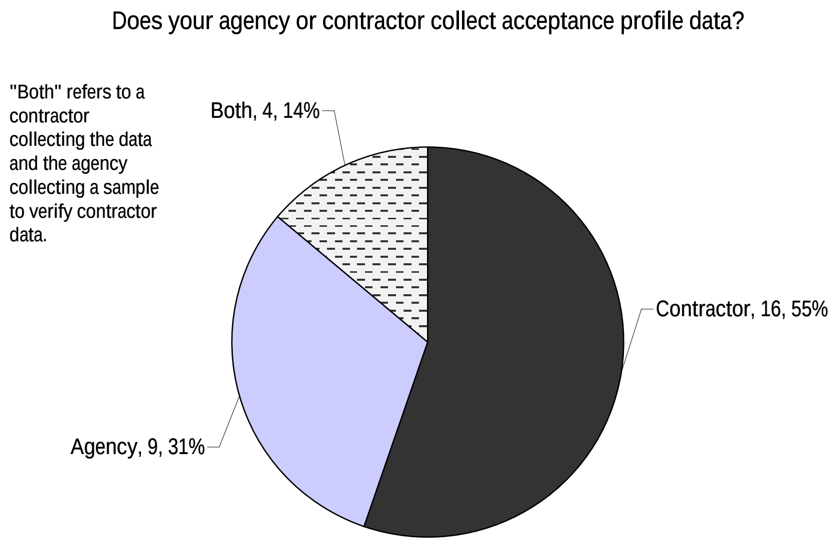


*Figure 5.2. Collection of Acceptance Profile Data.*

## 5.4 SMOOTHNESS INDEX USED ON NEW AC PAVEMENTS

About 40% of agencies who responded are using IRI as a smoothness index for their AC pavements (Figure 5.3). These agencies are using light weight and/or high speed inertial profilers for the determination of IRI.

## 5.5 NUMBER OF COLLECTED RUNS

MDT currently uses only one run to collect its IRI data. Over half of the agencies that have inertial profilers and responded to the survey also collect only one run (Figure 5.4). However, STE recommends collecting an additional run for quality control purposes.

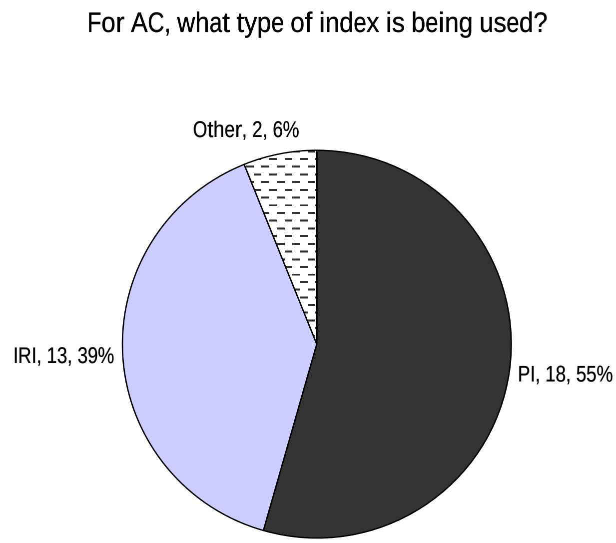


*Figure 5.3. Smoothness Index Used for New AC Pavements.*

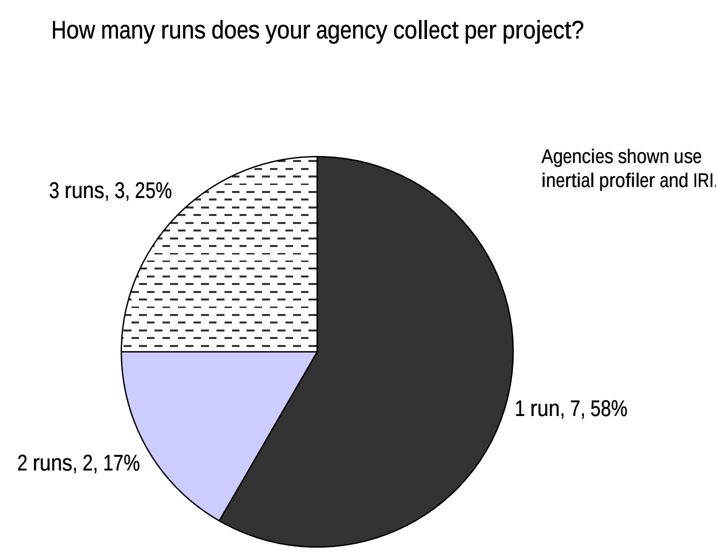


*Figure 5.4. Number of Collected Runs.*

## 5.6 BUMP SPECIFICATION

As shown in Figure 5.5, approximately 80% of agencies who responded have a bump specification for correcting localized surface profile defects. MDT uses a bump size of 0.4 in over 25 feet. As shown in Figure 5.6, this is consistent with most agencies practices as most agencies use a 0.3 to 0.4 in (7.62 to 10.16 mm) criterion over 25 feet (7.62 m).

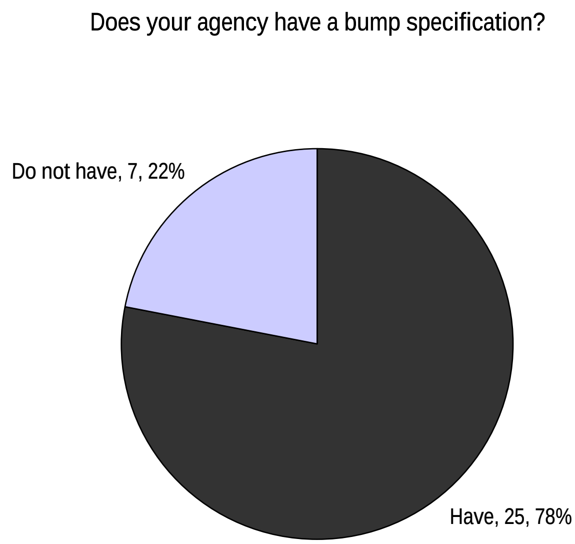


*Figure 5.5. Developed Bump Specification.*

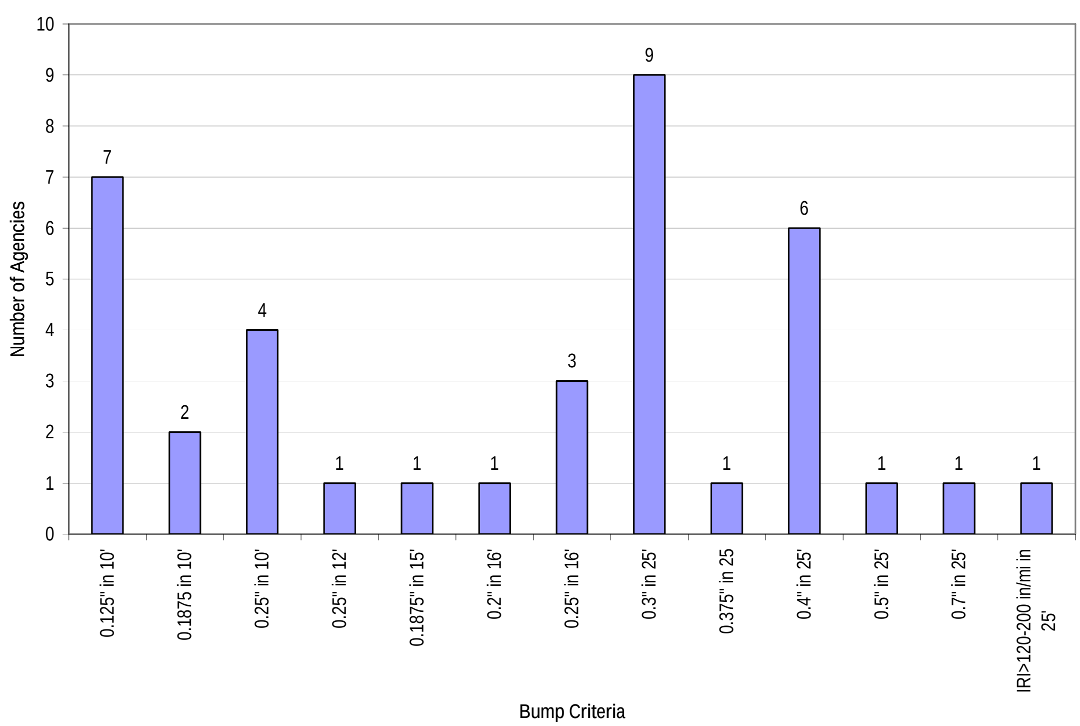


*Figure 5.6. Bump Size and Base Length for Agencies.*

## 5.7 MAXIMUM IRI LIMIT

Montana currently does not use a maximum threshold for IRI above which either corrective actions or rejection of the lot is required. This topic was discussed previously in Tasks A and B. Figure 5.7 represents a number of agencies that use a maximum IRI value to protect themselves against situations where a contractor accepts the penalty and does not attempt any corrective measures, leaving the agency with a "rough" road.

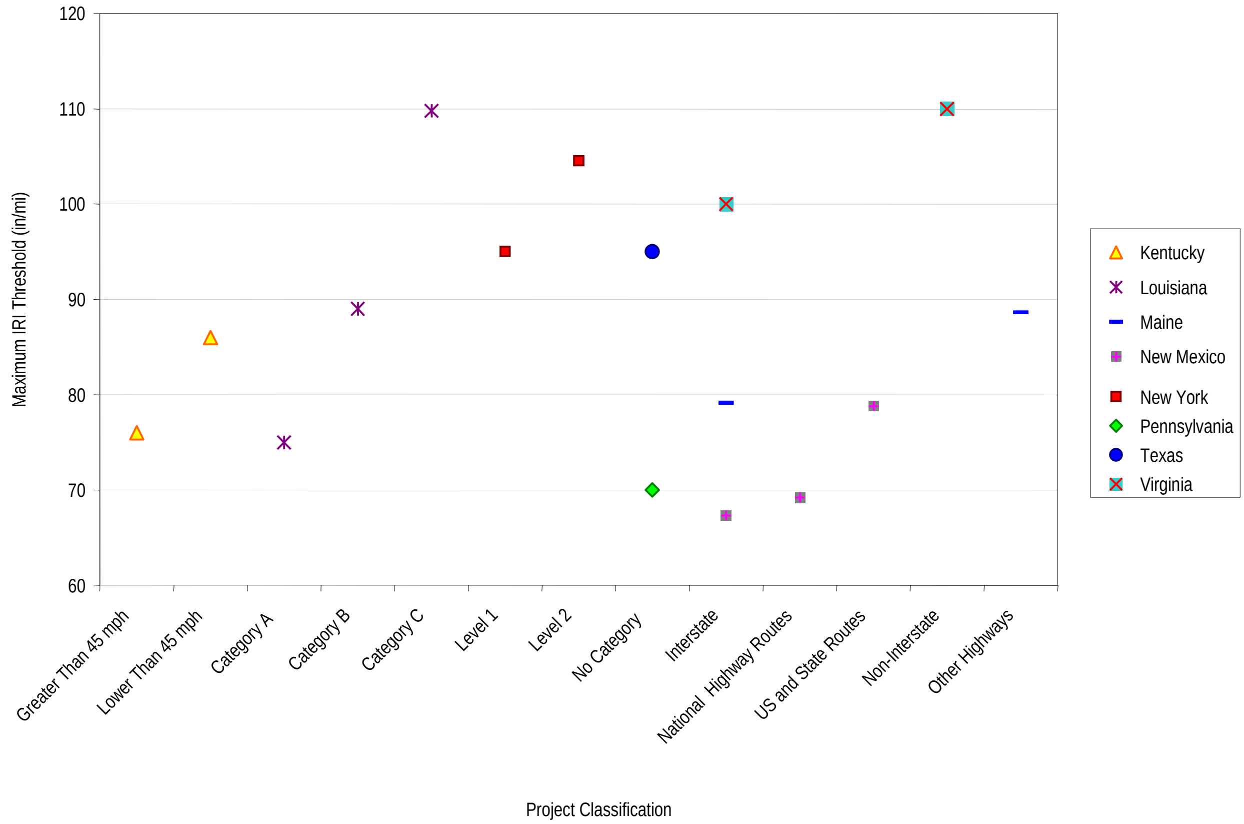


*Figure 5.7. Maximum IRI Threshold for Project Classifications.*

## 5.8 PROJECT CLASSIFICATION

The results of literature review and also the state of the practice survey clearly show that there is no "right" or "wrong" answer to the way agencies have categorized their project classifications (Figure 5.8). What is generally followed in agencies' ride specifications is a categorization based on prioritizing the most important (or traveled) roadways (i.e., interstate) with lower initial IRI's. This topic was previously discussed in Task B.

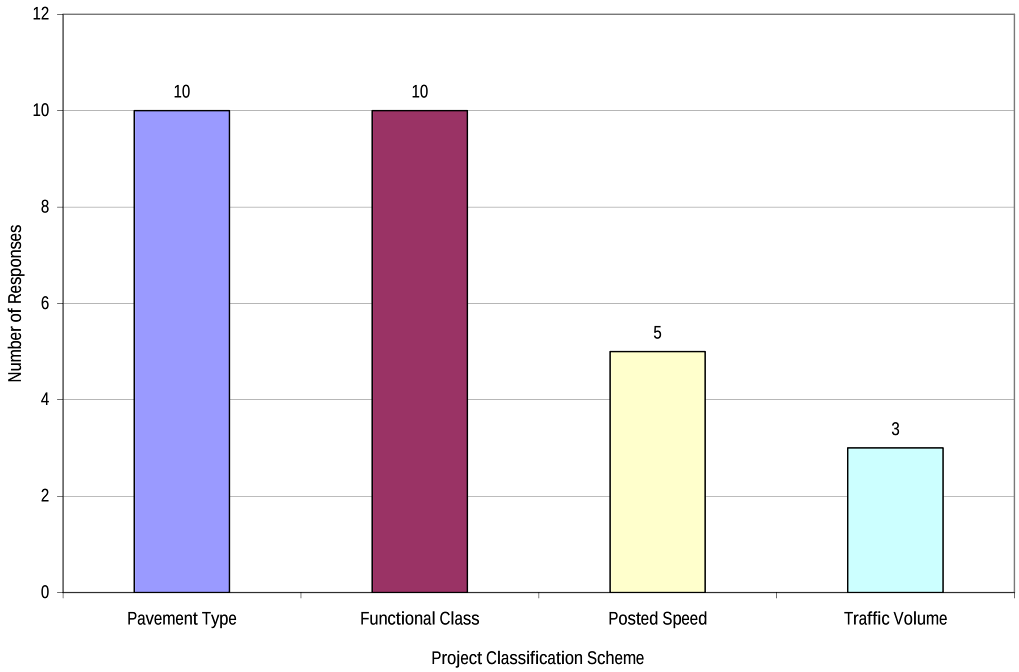


*Figure 5.8. Project Classifications Schemes.*

## 5.9 RIDE DATA COLLECTION EQUIPMENT

As shown in the following figures, over half of the agencies who responded are using inertial profilers (high speed and light weight) for collecting ride data. Figure 5.9 presents the results from the survey. Many agencies use multiple equipment; therefore, there are more responses than agencies who answered the survey. Figure 5.10 presents another interpretation of the survey results. It shows that 22% of the agencies that responded to the survey only use high speed profilers and that 62% use a high speed profiler in conjunction with other pieces of equipment.

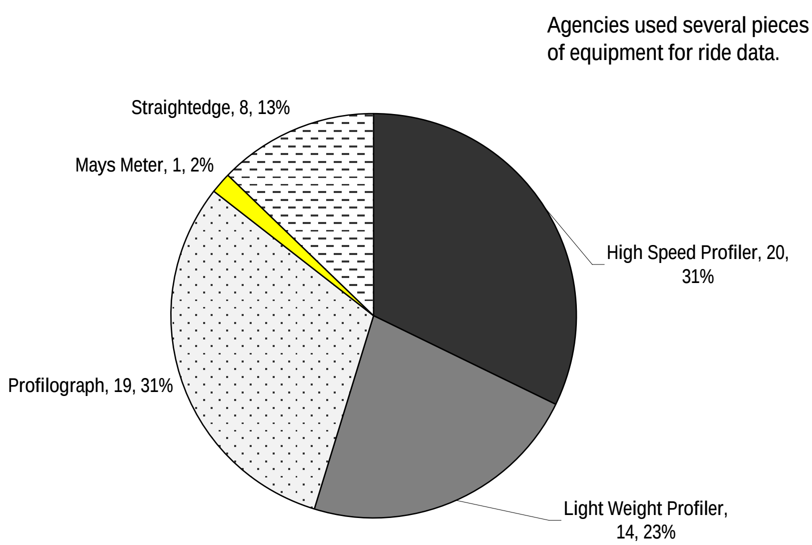


*Figure 5.9. Kind of Equipment Used to Collect Ride Data.*

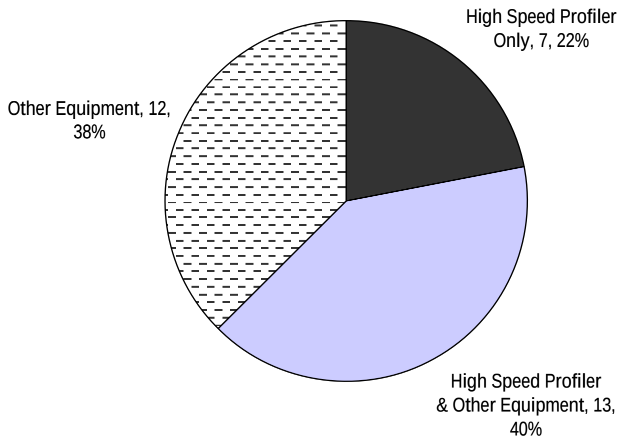


*Figure 5.10. Use of High Speed Profiler versus Other Kinds of Equipment.*

## 5.10 METHODOLOGY USED TO CALIBRATE EQUIPMENT

As shown in Figure 5.11, almost half of the agencies having inertial profilers use their own procedures for calibrating the equipment. The MT-422 document is an example of an agency developing its own procedure to calibrate the profilers. It is given that in almost all cases the vendors' input is utilized in developing the calibration procedures; however, it is critical to fine-tune the process to meet each agencies specific need.

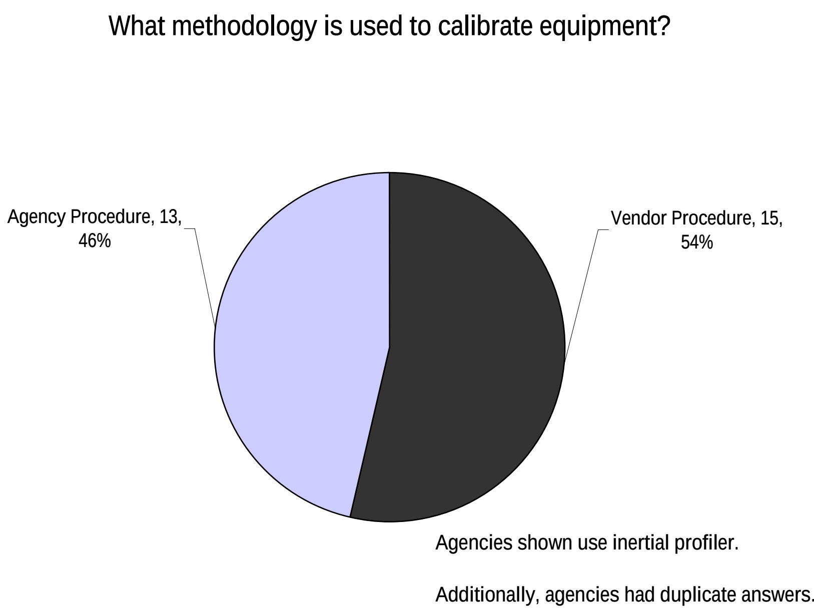


*Figure 5.11. Methodology Used To Calibrate Equipment.*

## 5.11 RATINGS FOR HIGH SPEED PROFILER

### *5.11.1 ACCURACY*

As shown in Figure 5.12, over half of the agencies that responded were satisfied with the accuracy of their data measurements.

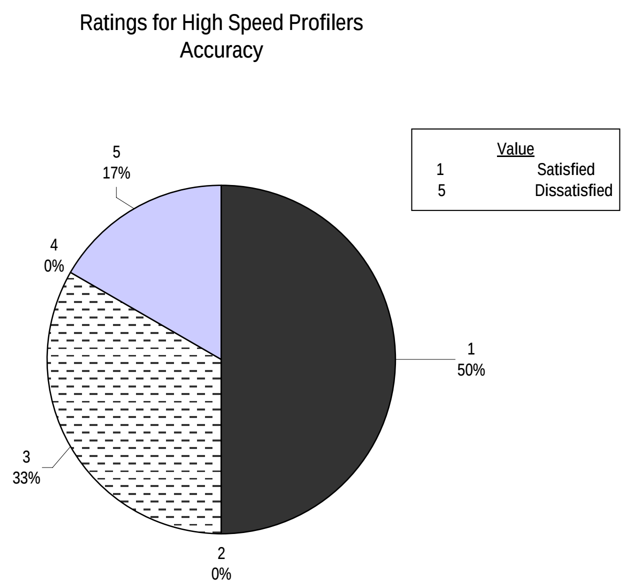


*Figure 5.12. Ratings for High Speed Profiler on Accuracy.*

### *5.11.2 REPEATABILITY*

Out of eighteen agencies who have high speed inertial profilers, over half are satisfied with the repeatability of their data measurements (Figure 5.13).

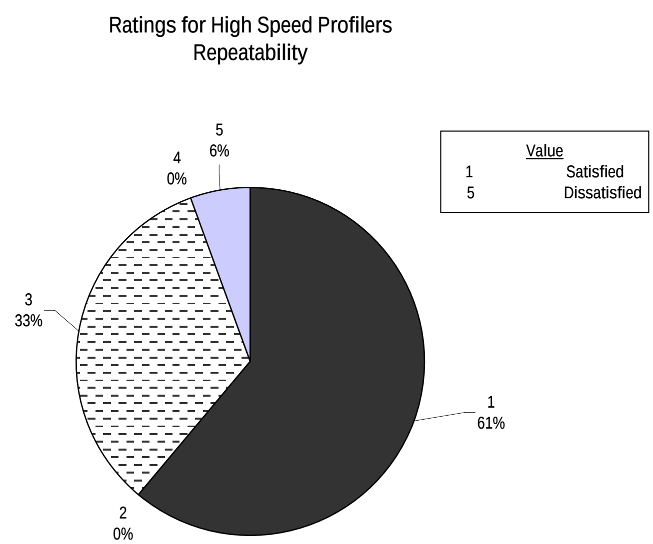


*Figure 5.13. Ratings for High Speed Profiler on Repeatability.*

### 5.11.3 CORRELATION WITH SAME MODEL

Out of eighteen agencies who have high speed inertial profilers, over half are satisfied with the accuracy of profile data collection using different profilers of the same type (between-equipment variability) (Figure 5.14).

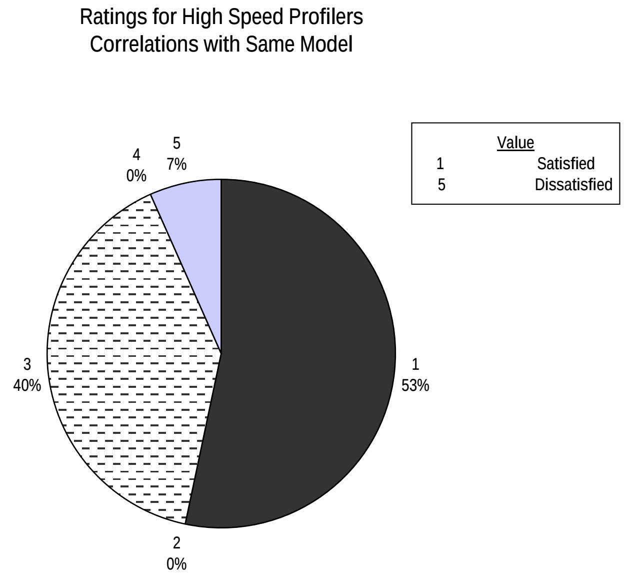


*Figure 5.14. Ratings for High Speed Profiler on Correlations with Same Model.*

### 5.11.4 EXPERTISE

Out of eighteen agencies that have high speed inertial profilers, about 20% are dissatisfied with the level of expertise required to operate the equipment (Figure 5.15). Routine personnel training is a critical step in having a successful state wide smoothness program. STE has emphasized the training in the QC/QA document developed for field and office data collection and analysis.

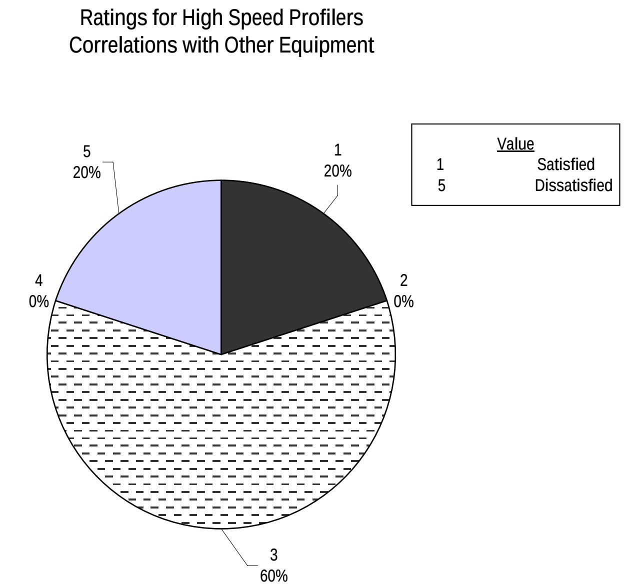


*Figure 5.15. Ratings for High Speed Profiler on Expertise Required.*

### 5.11.5 DATA REDUCTION EFFORTS

Data reduction efforts seem to be of some concern for agencies using inertial profilers (Figure 5.16). STE has emphasized the proper data reduction procedures in the QC/QA document developed for field and office data collection and analysis.

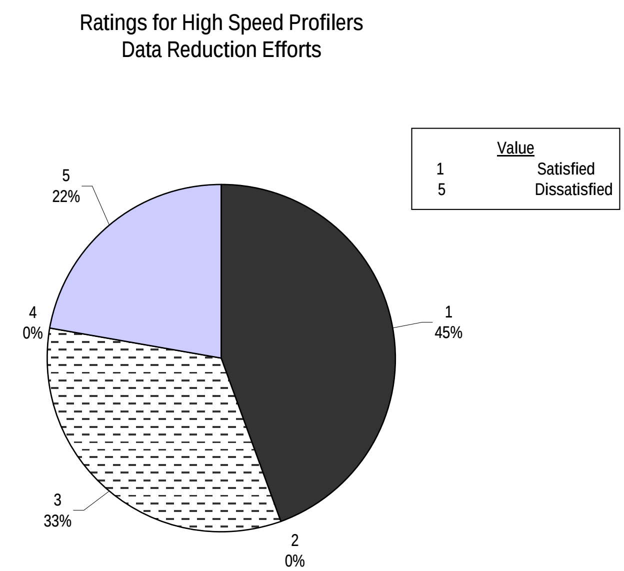


*Figure 5.16. Ratings for High Speed Profiler on Data Reduction Effort.*

### 5.11.6 GRIND IDENTIFICATION

Similar to MDT concerns, many other agencies are also having difficulties locating the must grind areas using inertial profilers (Figure 5.17). The reason for this can be a combination of data collection procedures (i.e., proper marking of the start point) and data analysis tools. STE has thoroughly addressed these issues in Tasks A, B, and D.

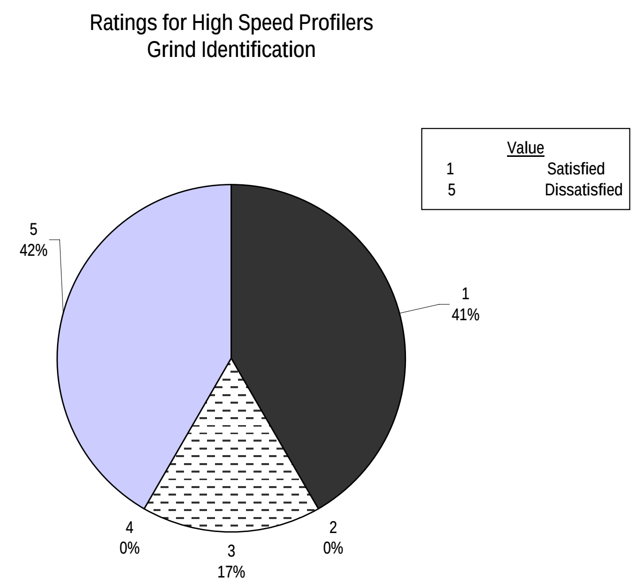


*Figure 5.17. Ratings for High Speed Profiler on Grind Identification.*

### 5.11.7 CALIBRATION OF EQUIPMENT

Generally, agencies calibrate their equipment sometimes during the year and right before testing a project. STE has developed a Profiler Operations Manual and modified the MT-422 to create a consistent and systematic way of calibrating the profilers on a pre-defined and routine schedule (Figure 5.18).

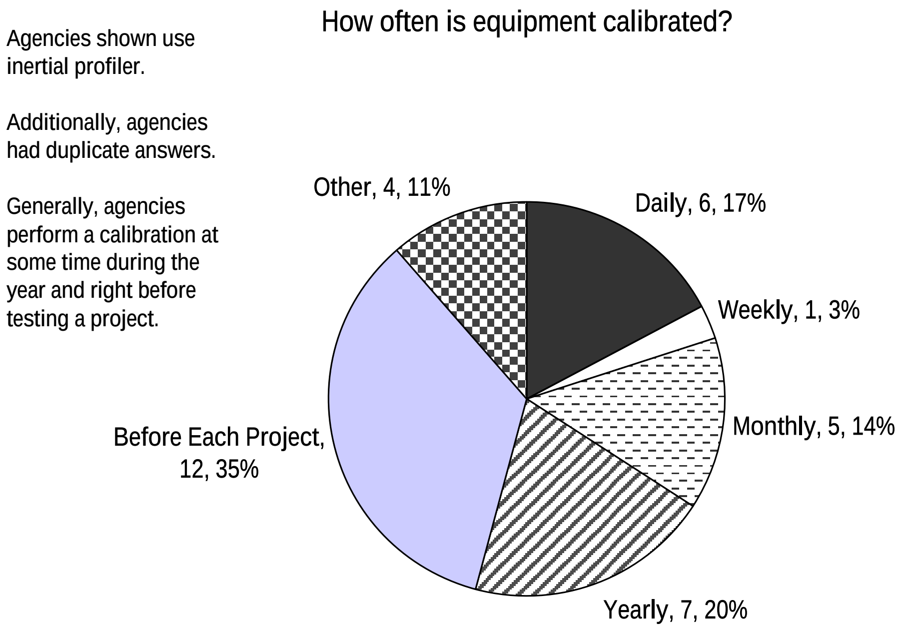


*Figure 5.18. Timeliness of Equipment Calibration.*

## 5.12 INCENTIVE / DISINCENTIVE PROGRAM

Most agencies who responded to the survey either have or are in the process of having an incentive/disincentive program for their flexible pavements based on smoothness criteria (Figure 5.19).

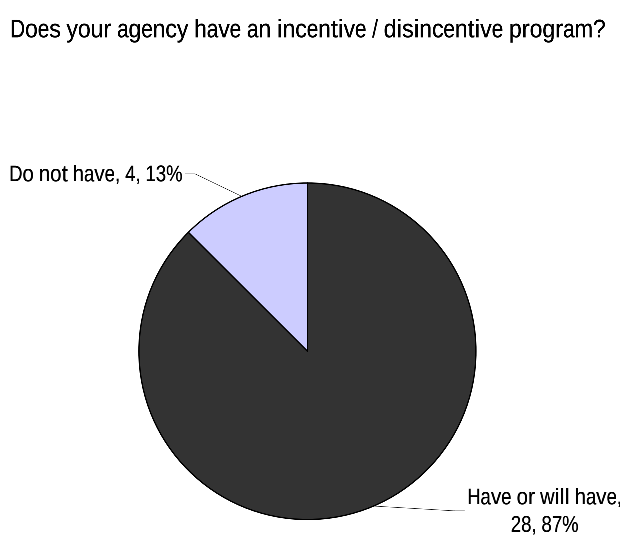


*Figure 5.19. Incentive / Disincentive Program.*

## 5.13 BLANKING BAND

Of the agencies who responded to the survey, many still use 0.2 in (5.08 mm) blanking band for their PI calculations (Figure 5.20). Montana has specified a zero blanking band for the determination of PI for the must grind areas. One of the key findings of this project is that the 0.4 in (10 mm) bump criterion defined in MDT current specification is independent of PI and also of blanking band. As discussed in Task D, all mentions of PI and blanking band have to be removed from the revised MDT specification.

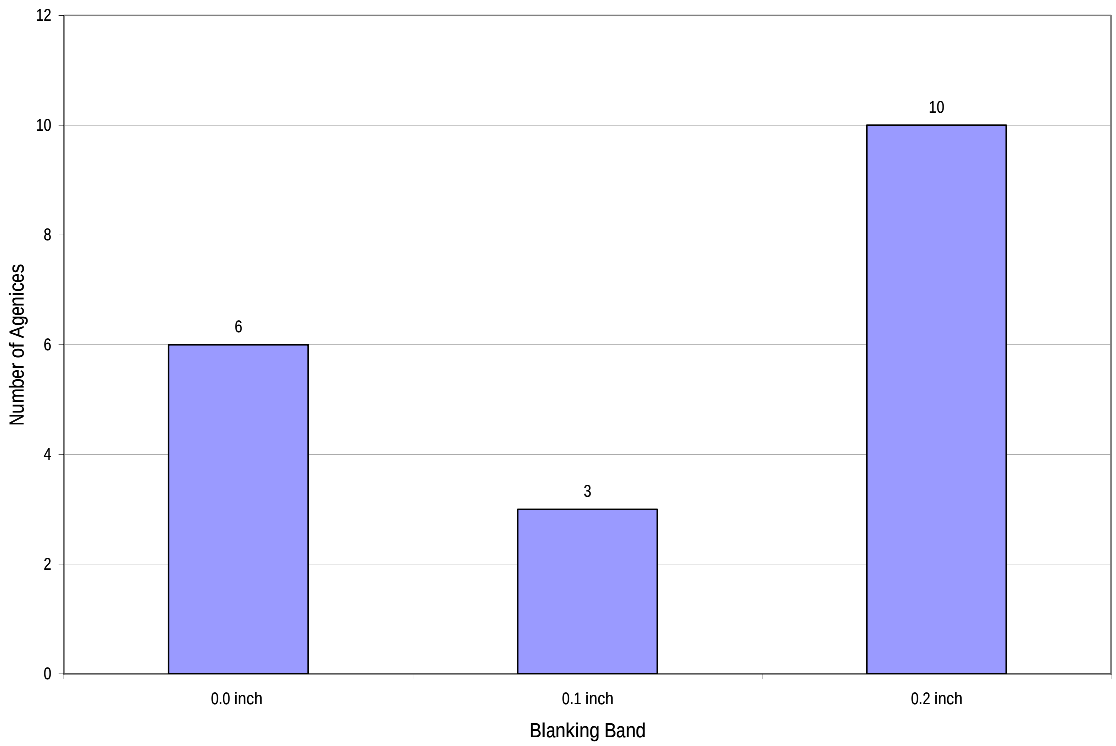


*Figure 5.20. Type of Blanking Band.*

## 5.14 ASSESSMENT OF CURRENT RIDE SPECIFICATION

Over 30% of agencies who responded to the survey believe that their current ride specifications need revisions or are inadequate (Figure 5.21).

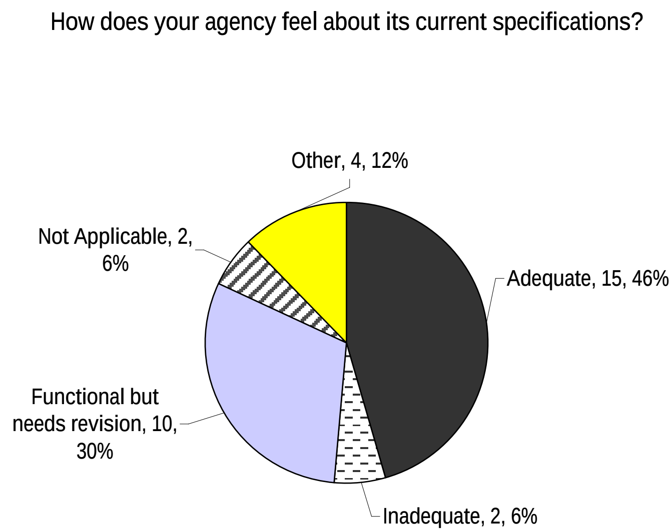


*Figure 5.21. Assessment of Ride Specification.*

## 5.15 RESULTS OF INCENTIVE / DISINCENTIVE PROGRAM ON INITIAL PAVEMENT SMOOTHNESS

As shown in Figure 5.22, close to half of the agencies who responded to the survey believe that their incentive/disincentive program has significantly improved smoothness of their roadways.

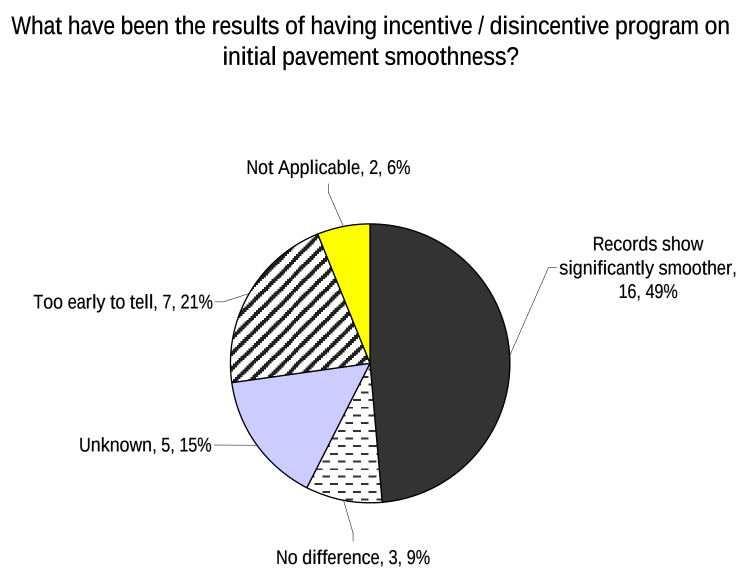


*Figure 5.22. Results of Incentive/Disincentive Program on Initial Pavement Smoothness.*

## 5.16 RESULTS OF INCENTIVE / DISINCENTIVE PROGRAM ON MATERIALS/CONSTRUCTION QC

As shown in Figure 5.23, over half of the agencies who responded to the survey believe that their incentive/disincentive programs have enhanced materials/construction quality control procedures.

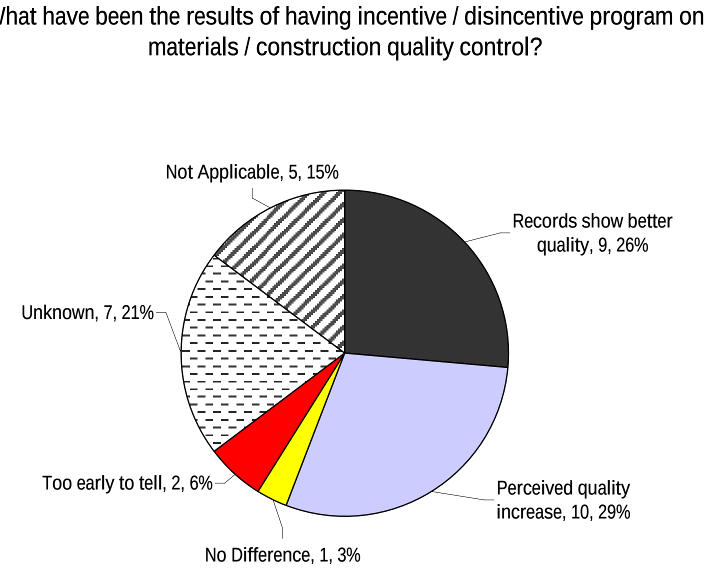


*Figure 5.23. Results of Incentive/Disincentive Program on Materials/Construction QC.*

## 5.17 RESULTS OF INCENTIVE / DISINCENTIVE PROGRAM ON OVERALL COST

Most agencies are still assessing the overall "direct" cost to the agency due to their incentive/disincentive program. As shown in Figure 5.24, three agencies believe that their programs have resulted in significant increase in payments to the contractors.

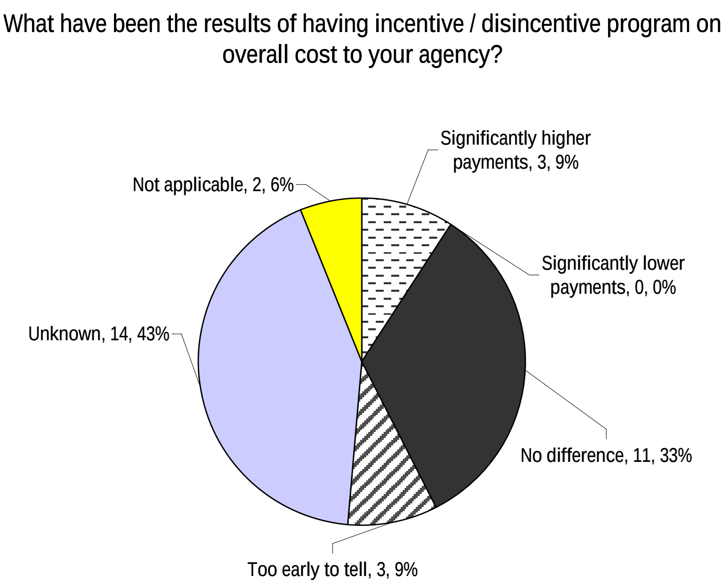


*Figure 5.24. Results of Incentive/Disincentive Program on Overall Cost to Agency.*

## 5.18 CORRECTION OF PROFILE DEFECTS

Similar to MDT, over half of the agencies who responded to the survey do not allow the contractor to correct profile defects in order to receive incentive pay (Figure 5.25).

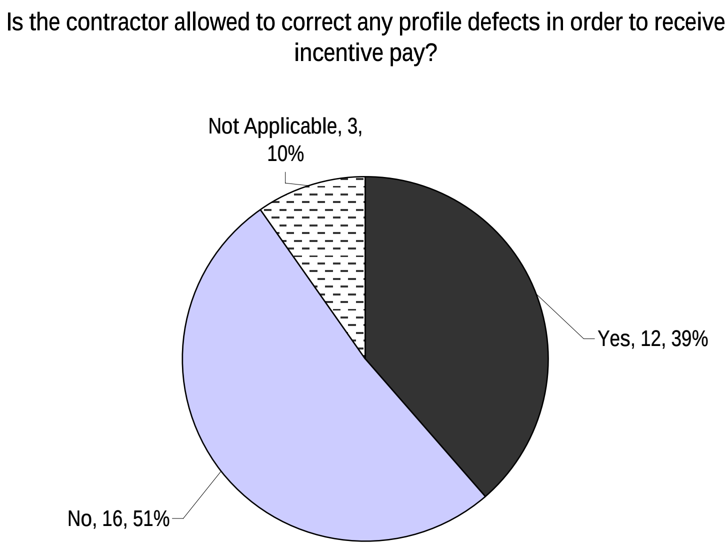


*Figure 5.25. Correction of Profile Defects.*

# 6.0 TASK D. RECOMMENDATIONS

In this section, STE provides a series of recommendations for enhancing MDT's current specification and profiling practices. These recommendations are based on work performed in Tasks A through C.

## 6.1 MDT RIDE SPECIFICATION ENHANCEMENTS

This section contains STE's recommendations on the number of project classifications, maximum IRI thresholds, and revised pay factor equations. The revised ride specification can be found in Appendix C.

### *6.1.1 APPROPRIATE NUMBER OF CLASSIFICATION SCHEMES*

STE activities under Tasks A through C clearly show that there is no unique methodology for project classification schemes for an agency to follow. Agencies have developed their project classification scheme to improve smoothness based on a combination of the following factors:

- Pre-pave IRI,
- Traffic volume,
- Roadway functional classification,
- Number of opportunities to improve the road,
- Speed limits, and
- Pavement type.

Many of the above factors are not independent of each other. For example, roadway functional class, speed limits, and traffic volumes have a direct relationship in many parts of the country. Freeways normally carry higher traffic volumes at higher speeds than other roadway functional classes. Also, in states such as Montana, where very important roadways carry lesser traffic volume as compared to some other parts of the country, classification of the roadways by traffic volumes may not be appropriate.

As discussed in Task A, the STE project team agrees with MDT's current practice of separating projects into different classes based on:

- Pre-pave IRI and
- Number of opportunities.

The target IRI values set in the current MDT specification are directly related to these two parameters. In addition, the number of opportunities to improve the road is "rarely" a function of pre-pave IRI alone. Many other factors including existing distress conditions, improvements to roadway geometry, and financial constraints have more impact on defining the number of "opportunities for roadway improvement" than pre-pave smoothness.

Each opportunity to improve the ride is one of the following:

1. Placing a gravel base or surfacing course,
2. Placing plant mix bituminous base,
3. Placing cement treated base,
4. Placing pulverized plant mix surfacing,
5. Milling,
6. Cold recycling (milling and laydown), or
7. Each full 0.15 ft (45 mm) increment of new plant mix surfacing.

STE obtained a series of projects from MDT containing project classification information and post-pave IRI. Most of the projects obtained were Classes I and II. There were a few Class III and Class IV projects. Table 6.1 presents the average post-pave IRI per MDT class for the recent MDT projects.

*Table 6.1. Average Post-Pave IRI per MDT Class.*

| MDT Project Classification | Count[1] | Post-Pave IRI Average (in/mi) [m/km] | Minimum IRI (in/mi) [m/km] | Maximum IRI (in/mi) [m/km] | Standard Deviation (in/mi) [m/km] |
|---|---|---|---|---|---|
| MDT Class I | 63 | 50 [0.79] | 38 [0.60] | 66 [0.95] | 7 [0.11] |
| MDT Class II | 13 | 51 [0.80] | 44 [0.69] | 58 [0.92] | 4 [0.06] |
| MDT Class III | 2 | 46 [0.73] | 45 [0.71] | 47 [0.74] | 1 [0.02] |
| MDT Class IV | 2 | 61 [0.96] | 59 [0.93] | 63 [0.99] | 3 [0.05] |

*[1]Count represents a lane of data (e.g., control number 1022, northbound drive lane).*

As specified in the current MDT ride specification, the target values for IRI for Class I and II are relatively close (i.e., 46-65 in/mi (0.73-1.03 m/km) versus 56-75 in/mi (0.88-1.18 m/km)). However, the acceptable target range of 20 in/mi (0.32 m/km) may be too wide. As discussed in Task A, STE understands that this was probably set to alleviate reliability concerns of taking one profile run at each pavement segment.

Activities under Tasks A through C also indicated that two opportunities would be sufficient to achieve the target IRI. The third opportunity is normally the result of reconstruction due to other factors including pavement age, geometric improvements, and existing distress conditions and has little to do with the pre-pave IRI.

STE recommends the following changes to the current project classification scheme:

*Create New Category 1*

Based on a revised MT-422 and better in place QC/QA procedures, STE recommends a target range of 50-55 in/mi (0.79-0.87 m/km) for the new Category 1 projects. The new Category 1 projects will have the following attributes:

- Target IRI set at 50 to 55 in/mi (0.79-0.87 m/km), and
- Project with two or more opportunities to improve the ride, or
- Single lift overlays with pre-pave IRI < 110 in/mile (1.74 m/km).

Per Section 6.1.2, the maximum post-pave IRI should not be greater than 90 in/mi (1.42 m/km).

*Create New Category 2*

The new Category 2 project will have the following attributes:

- Target IRI set at 55 to 60 in/mi (0.87-0.95 m/km) and
- Single lift overlays with pre-pave IRI value ≥ 110 in/mi (1.74 m/km) and < 190 in/mi (3.00 m/km).

Per Section 6.1.2, the maximum post-pave IRI should not be greater than 95 in/mi (1.50 m/km).

*Exception for High Pre-Pave IRI Roadways*

To keep the roadways as smooth as possible, it is recommended that roadways with pre-pave IRI values above 190 in/mi (3.00 m/km) be treated as a Category 1 project with two or more opportunities to improve the ride. However, if for other reasons (i.e., budgetary) only one opportunity is reasonable and/or feasible then it is suggested that MDT should specify that the maximum post-pave IRI should not be more than 50% of the pre-pave IRI. For those cases, STE does not suggest any pay adjustment factor based on smoothness; however, corrective actions need to be taken at contractor's expense if post paving IRI is greater than 50% of pre-pave IRI.

Evaluating the same series of projects, Table 6.2 presents the average post-pave IRI per Category. Category 1 was comprised of Class I-IV. Category 2 was comprised of Class II. The average post-pave IRI was the same for each category.

*Table 6.2. Average Post-Pave IRI per Category.*

| Project Category | Count[1] | Post-Pave IRI Average (in/mi) [m/km] | Minimum IRI (in/mi) [m/km] | Maximum IRI (in/mi) [m/km] | Standard Deviation (in/mi) [m/km] |
|---|---|---|---|---|---|
| Category 1 | 73 | 51 [0.80] | 38 [0.60] | 66 [1.04] | 7 [0.11] |
| Category 2 | 7 | 51 [0.80] | 47 [0.74] | 58 [0.92] | 5 [0.08] |

*[1]Count represents a lane of data (e.g., control number 1022, northbound drive lane).*

### *6.1.2 MAXIMUM IRI THRESHOLD PER CLASSIFICATION SCHEME*

The need for a maximum IRI threshold has been discussed in Tasks A, B, and C. It is recommended that for Category 1 projects the maximum acceptable IRI limit be set at 90 in/mi. On any roadway segments having a post-pave IRI greater than 90 in/mi, the contractor is required to remove and replace the segment by milling 0.15 feet and replacing with new material meeting the original contract requirements.
The maximum pay adjustment factor possible after corrective action is taken will be 1.00.

It is recommended for Category 2 projects that the maximum acceptable IRI limit be set at 95 in/mi. On any roadway segment having a post-pave IRI greater than 95 in/mi, the contractor is required to remove and replace the segment by milling 0.15 feet and replacing with new material meeting the original contract requirements. The maximum pay adjustment factor possible after corrective action is taken will be 1.00.

### *6.1.3 APPROPRIATE PAY FACTOR EQUATION TO REPLACE THE EXISTING STEP FUNCTION*

Figure 6.1 presents the current IRI targets for the MDT classes with the average post-pave IRI's shown in Table 6.1. The average post-pave IRI for Class I and Class IV was within the target range. The average post-pave IRI value for Class II and Class III was better than the target range. Figure 6.1 clearly shows that the contractors have no difficulty achieving or surpassing the targets range for each MDT Class.

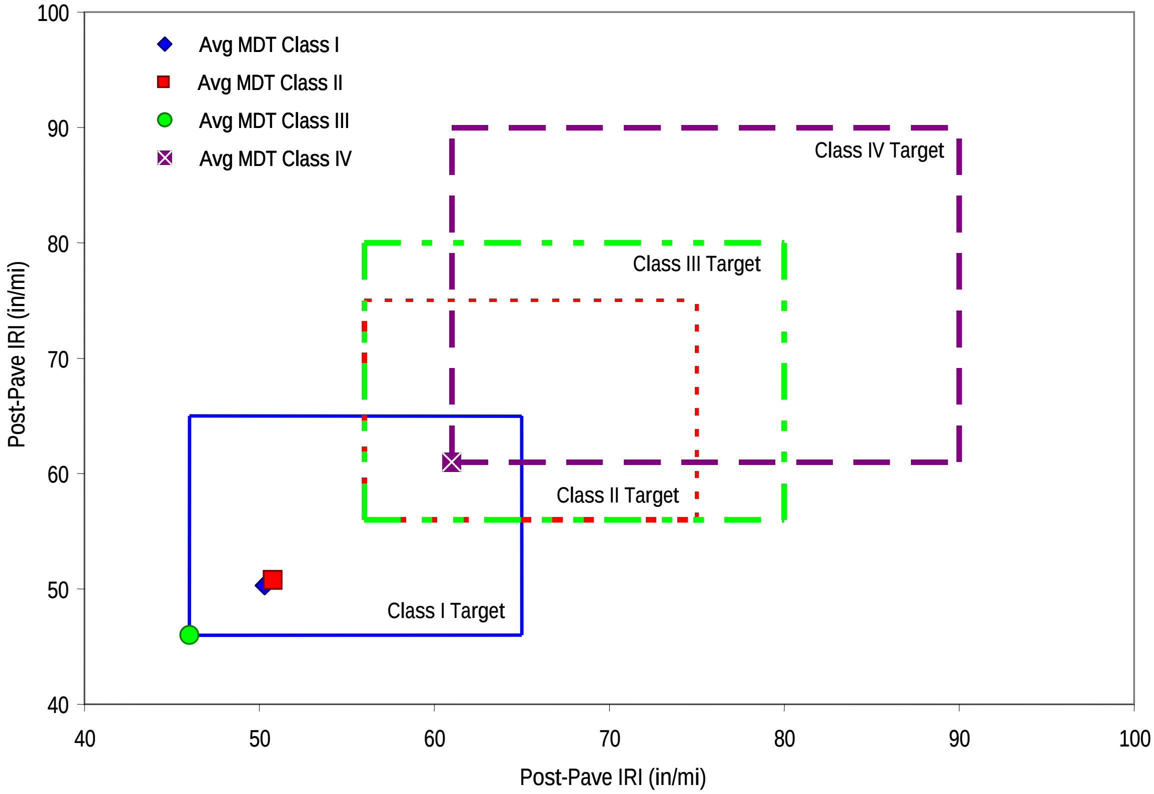


*Figure 6.1. Average Post-Pave IRI & Class Target Range.*

Figure 6.2 presents the new category targets and current IRI targets for the MDT classes with the average post-pave IRI's shown in Table 6.1. This figure illustrates where the new category targets are located compared with the current class targets and their reduced size compared with the current class targets.

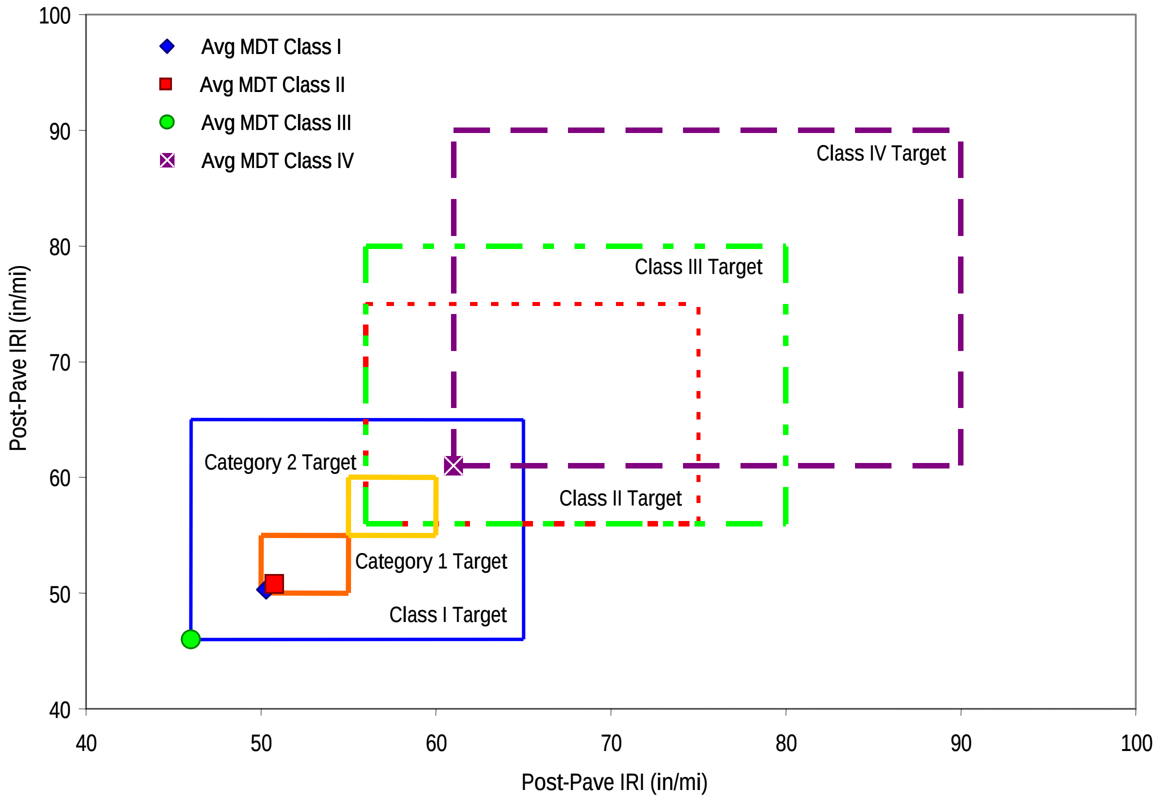


*Figure 6.2. Class versus Category Target Range.*

Figure 6.3 presents the new category targets the average post-pave IRI's shown in Table 6.2. The average post-pave IRI was the same for each category. The average post-pave IRI for Category 1 projects was within the target range. The average post-pave IRI for Category 2 was better than the target range. Figure 6.3 clearly shows that the contractors would have no difficulty achieving or surpassing the targets range for each category.

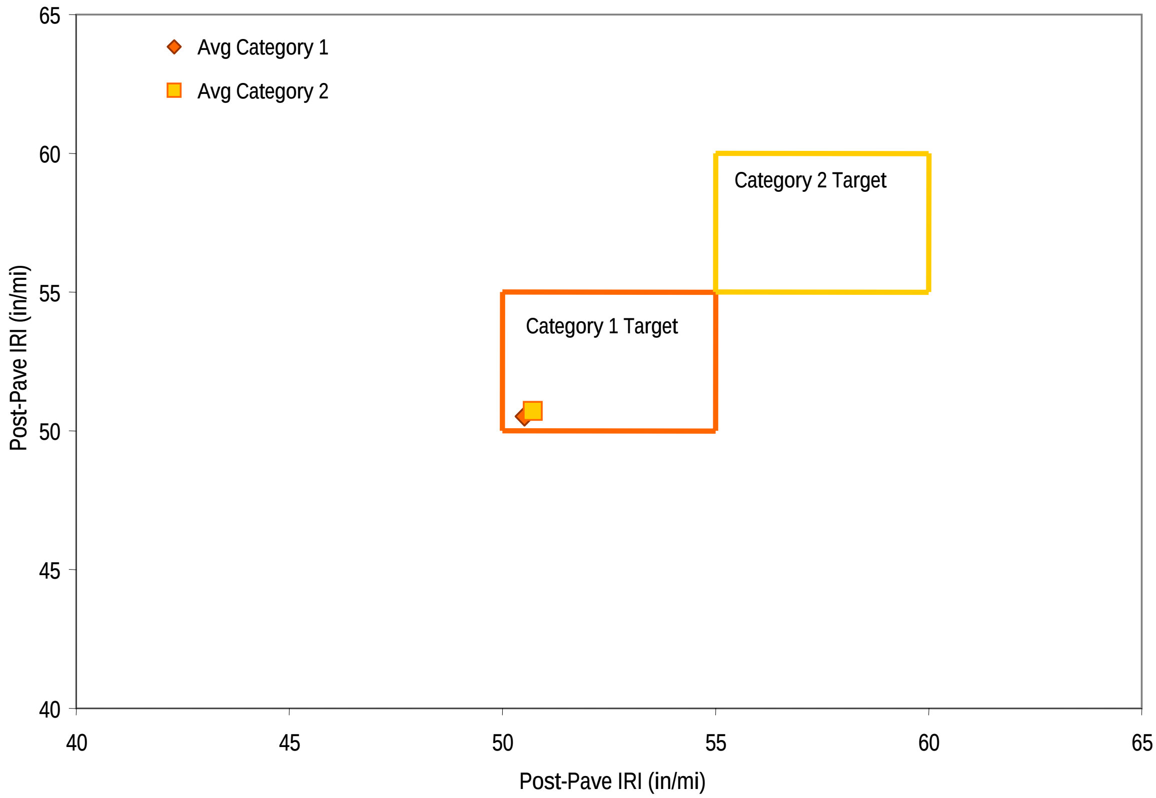

*Figure 6.3. Average Post-Pave IRI & Category Target Range.*

Based on discussions with MDT and the literature search, STE developed gradual pay adjustment factor relationships to replace the class step functions. In Figure 6.4 the new pay adjustment factor relationships for each category are shown versus the current class step functions. Figure 6.5 presents just the new pay adjustment factor relationships more clearly (e.g., less lines presented). Tables 6.3 and 6.4 describe the relationships in a tabular format.

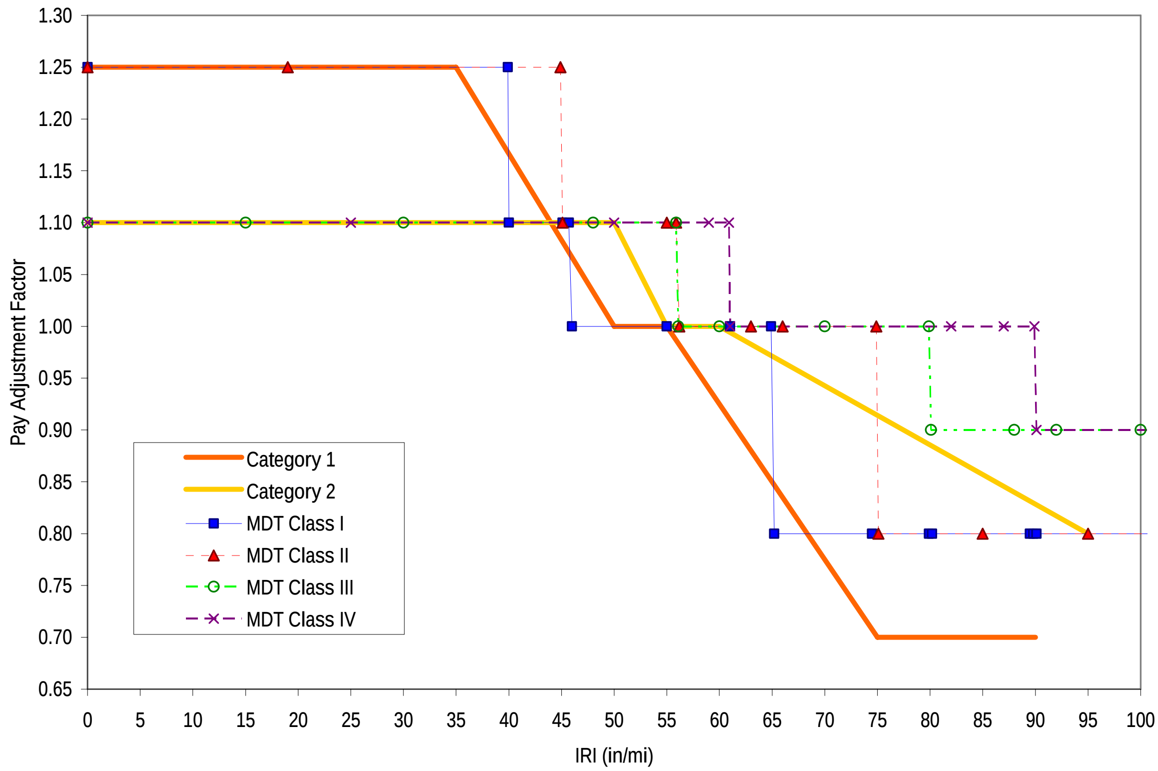


*Figure 6.4. Class versus Category Pay Adjustment Factor Relationships.*

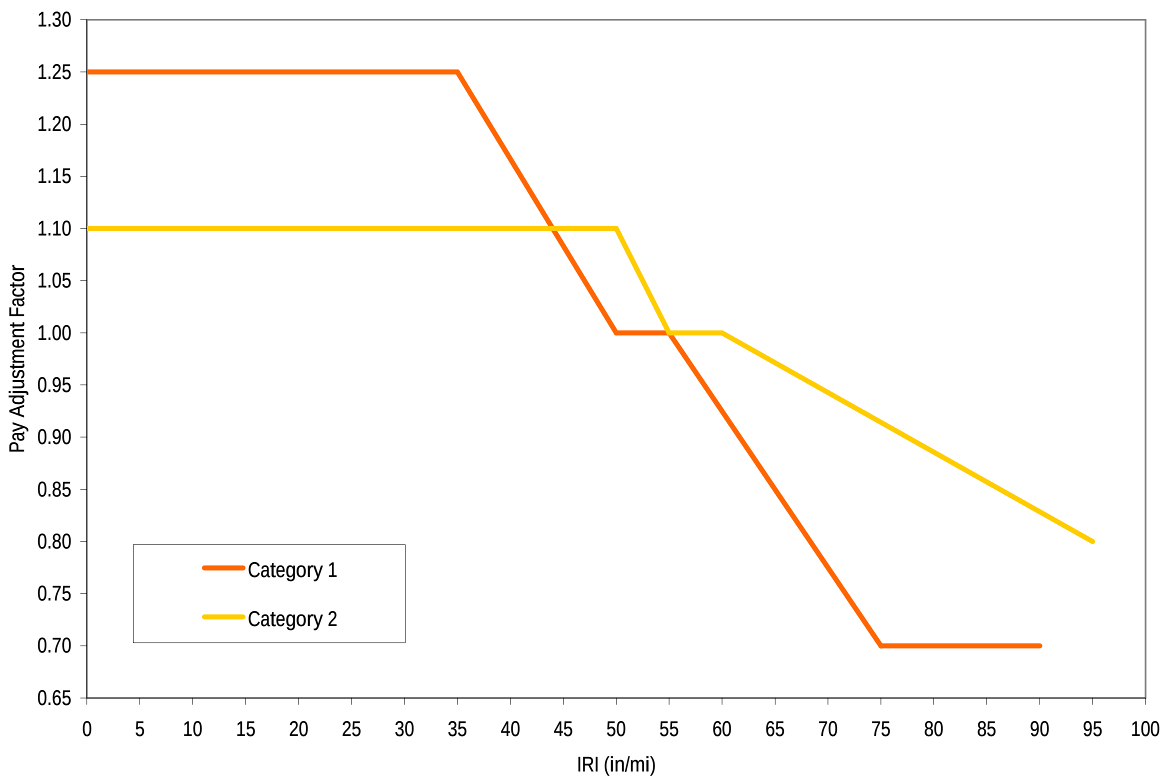


*Figure 6.5. Category Pay Adjustment Factor Relationships.*

*Table 6.3. New Category 1 Pay Adjustment Factor Relationship.*

| IRI (in/mi) [m/km] | Pay Adjustment Factor# |
|---|---|
| < 35<br>< [0.55] | 1.25 |
| 35 – 50<br>[0.55 – 0.79] | 1.845 – 17/1000 * IRI |
| 50 < IRI <55<br>[0.79 < IRI < 0.87] | 1.00 |
| 55 – 75<br>[0.87 – 1.18] | 1.825 – 3/200 * IRI |
| 75 < IRI <90<br>[1.18 < IRI < 1.42] | 0.70 |
| > 90<br>> [1.42] | Corrective Action Required<br>(Initially Assumed as a Zero Pay) |

*#Use only US Customary Units with pay adjustment factor relationships.*

*Table 6.4. New Category 2 Pay Adjustment Factor Relationship.*

| IRI (in/mi) | Pay Adjustment Factor# |
|---|---|
| < 50<br>< [0.79] | 1.10 |
| 50 – 55<br>[0.79 – 0.87] | 2.100 - 1/50 * IRI |
| 55 < IRI <60<br>[0.87 < IRI < 0.95] | 1.00 |
| 60 – 95<br>[0.95 – 1.50] | 1.343 - 1/175 * IRI |
| > 95<br>> [1.50] | Corrective Action Required<br>(Initially Assumed as a Zero Pay) |

*#Use only US Customary Units with pay adjustment factor relationships.*

### *6.1.4 ECONOMIC COMPARISON ANALYSES OF NEW CATEGORIES VERUS CLASS*

STE conducted an economic comparison between the new categories versus the current classification scheme. STE evaluated a total of 53 lanes of data, where 47 lanes are Category 1 and 6 lanes are Category 2.

The initial comparison evaluated total payment per lane regardless of whether the lane received an incentive or disincentive. Table 6.5 shows the total payment of the new categories versus what was paid. This shows that the new payment system would have paid approximately 58% of the amount that was paid for the 47 Category 1 lanes. For Category 2, the new payment system would have paid approximately 52% of the amount paid for the 6 Category 2 lanes.

Figure 6.6 and 6.7 present the current payment for all the lanes versus the new payment for Category 1 and 2. The line represents the difference between the new and the current payment.

*Table 6.5. Total Payment Analysis.*

| Category | Current Payment System | New Payment System | Δ | % of Current Payment |
|---|---|---|---|---|
| 1 | $307,683.68 | $179,082.98 | $ (128,600.70) | 58% |
| 2 | $43,120.13 | $22,389.19 | $ (20,730.94) | 52% |

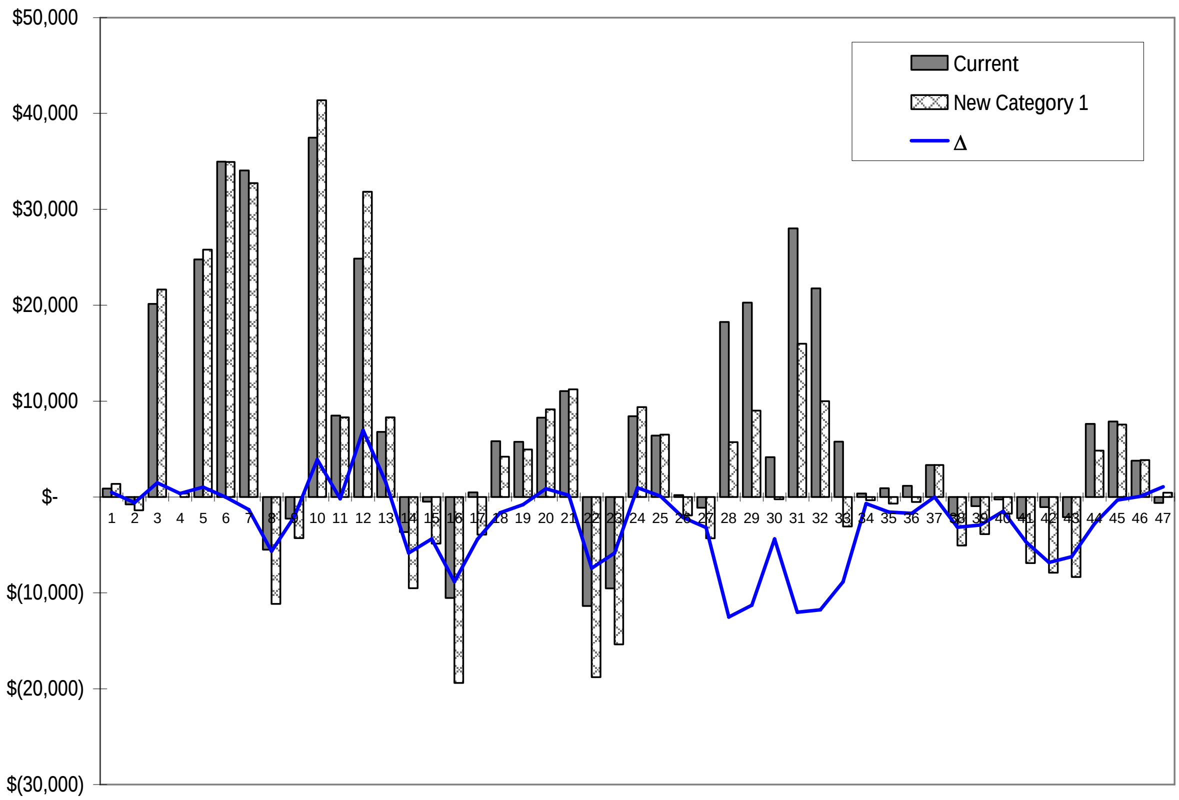


*Figure 6.6. Category 1 Total Payments.*

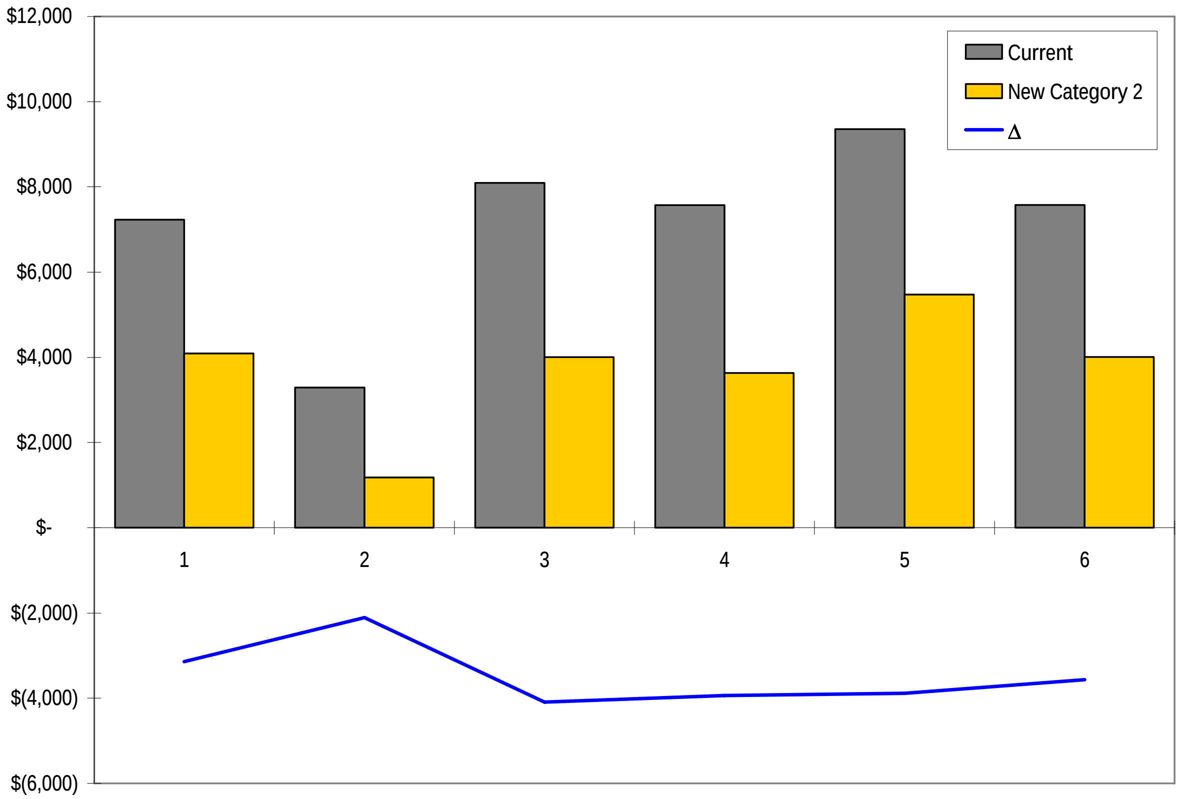


*Figure 6.7. Category 2 Total Payments.*

Next, STE evaluated only the lanes where an incentive occurred. There were 31 lanes for Category 1 and 6 lanes for Category 2. Table 6.6 shows the incentive payment of the new categories versus what was paid. This shows that the new payment system would have paid approximately 83% of the amount that was paid for the 31 Category 1 lanes. For Category 2, the new payment system would have paid approximately 52% of the amount paid for the 6 Category 2 lanes.

Figure 6.8 and 6.9 present the current incentive payment for all the lanes versus the new payment for Category 1 and 2. The line represents the difference between the new and the current payment.

The incentive analysis shows that for Category 1 the incentive is relatively close to the current payment. The fact that is slightly less may encourage the contractors to construct a "smoother" road. For Category 2, the incentive is approximately half of the current payment.

*Table 6.6. Incentive Payment Analysis.*

| Category | Current Payment System | New Payment System | Δ | % of Current Payment |
|---|---|---|---|---|
| 1 | $362,071.90 | $301,493.58 | $ (60,578.32) | 83% |
| 2 | $43,120.13 | $22,389.19 | $ (20,730.94) | 52% |

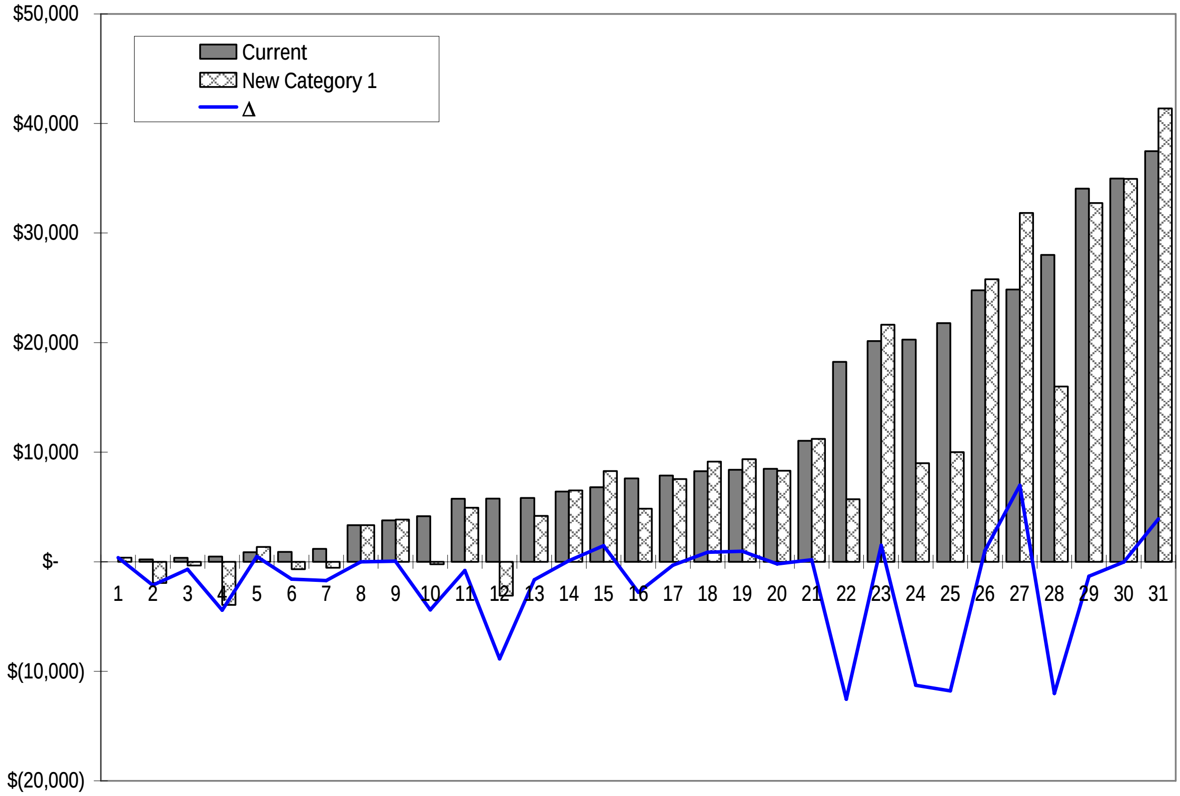


*Figure 6.8. Category 1 Incentive Payments.*

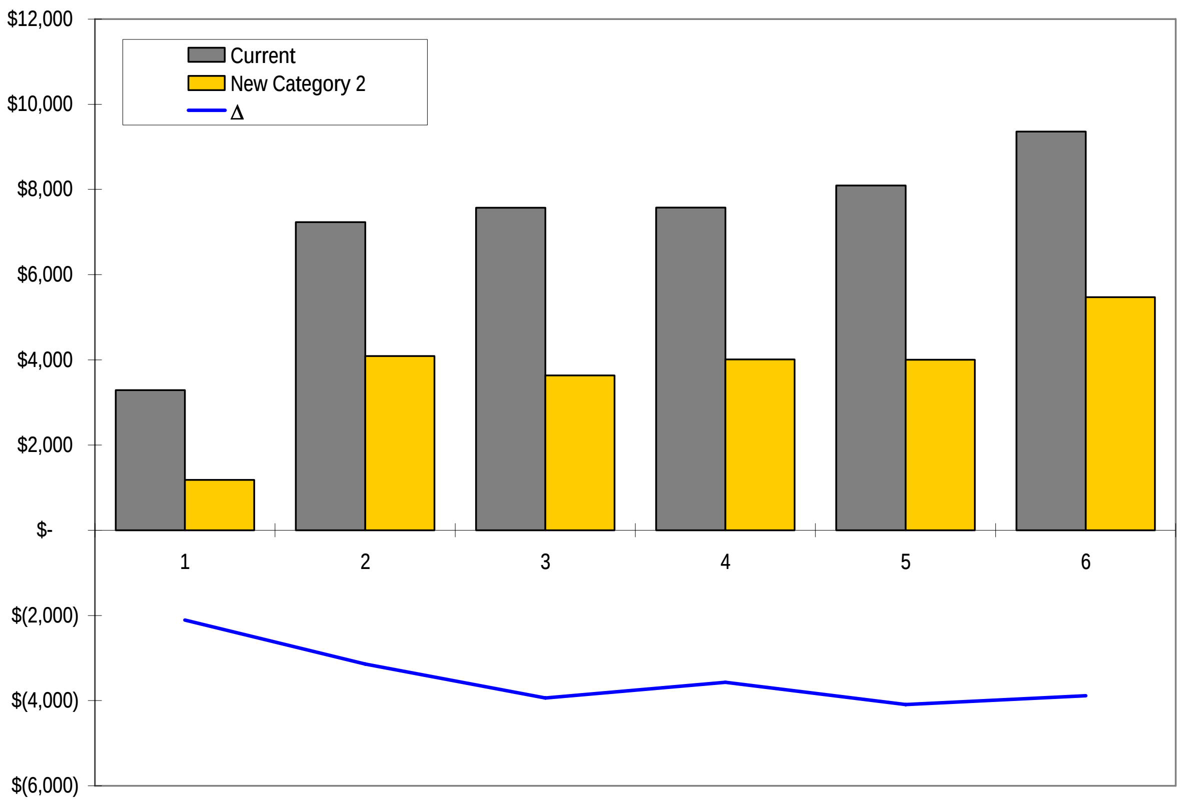


*Figure 6.9. Category 2 Incentive Payments.*

Next, STE evaluated only the lanes where a disincentive occurred. There were only 16 lanes for Category 1 and none for Category 2. Table 6.7 shows the disincentive payment of the new categories versus what was paid. This shows that the contractor would have paid approximately 225% more than they paid in the current system.

Figure 6.10 presents the current disincentive payment for all the lanes versus the new payment for Category 1. The line represents the difference between the new and the current payment.

The disincentive analysis shows that for Category 1 if the contractor does not construct a "smooth" road, the penalty is approximately two times the current disincentive. This disincentive should help the construction "smoother" roads.

*Table 6.7. Disincentive Payment Analysis.*

| Category | Current Payment System | New Payment System | Δ | % of Current Payment |
|---|---|---|---|---|
| 1 | $ (54,388.21) | $ (122,410.59) | $ (68,022.38) | 225% |
| 2 | - | - | - | - |

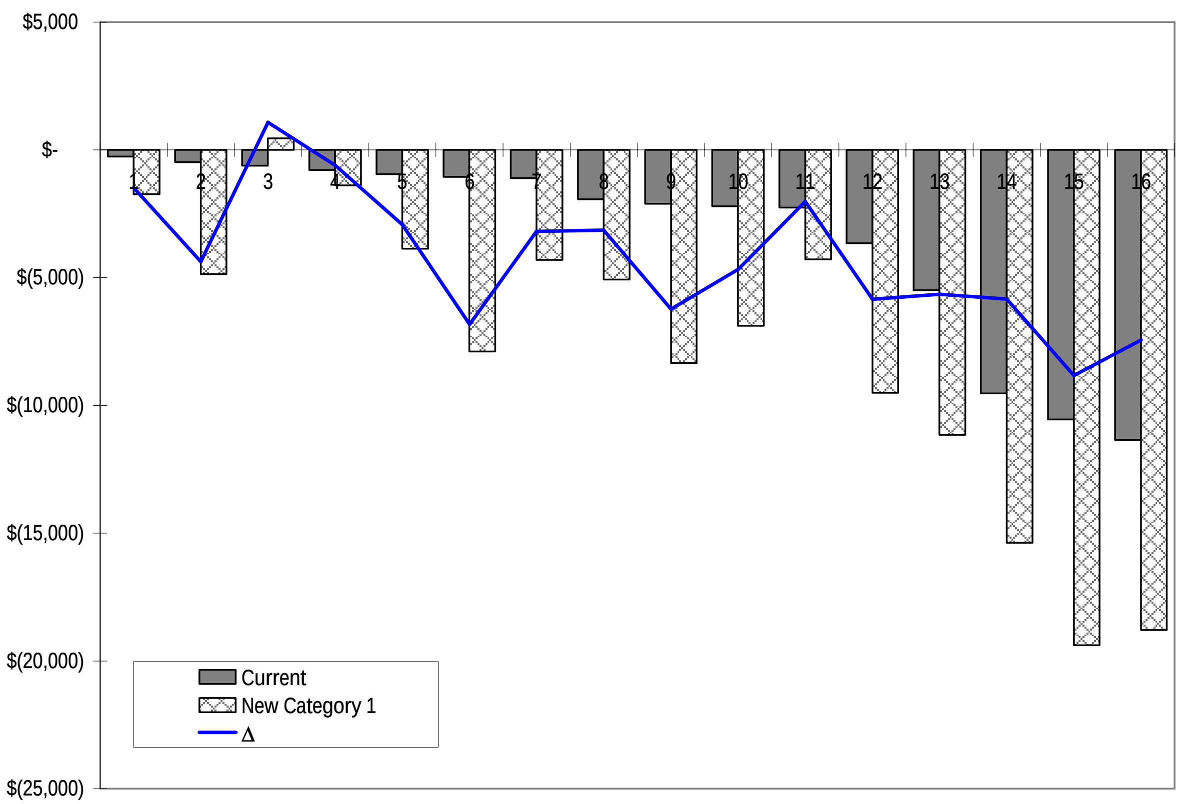


*Figure 6.10. Category 1 Disincentive Payments.*

### *6.1.5 IDENTIFICATION OF THE EXACT LOCATIONS OF THE "MUST GRINDS"*

Bump identification is a concern for all agencies including MDT. Using a non-contact type instrument to locate bumps is difficult. Although a profiler collects an enormous amount of data, the data goes through various processes (i.e., filtering) that can diminish the height of a "bump".

MDT stated during the kick-off meeting that on occasion there were problems exactly locating "must grinds". This occurred when profiler operators used stationing (e.g., starting point was 15+00) for the starting point rather than zero (e.g., 0 ft). As discussed previously, the problem with the use of stationing is that the DMI recorded stationing will unlikely match the roadway stationing. The roadway stationing is measured along the centerline of the project while the DMI recorded stationing will be along the test lane (e.g., wheel path). MDT also stated that when the profiler operators used zero as the starting point, the MDT Project Managers were able to drive to the exact locations of the "must grinds" easily.

STE recommends using only zero as a starting point for all data collection. The starting point (e.g., construction markings) should be well defined in order to locate at a later date.

In Section 4.2.4 of the Profiler Operations Manual, STE has recommended that MDT should try to initiate data collection with the profiler's photocell in conjunction with reflective tape and or cones. Using the photocell to initiate data collection may help eliminate errors caused by later or early pendant starts (e.g., starts using keyboard, keypad or button).

### *6.1.6 SURFACE PROFILE DEFECTS*

As stated in Tasks A and B, STE believes that the MDT's current method of analyzing surface profile defects using the ProScan software is independent of Profile Index (PI) and also independent of the blanking band. The revised ride specification should have no reference to PI and blanking band. It should merely state that any surface defect greater then 0.4 inches (10 mm) in 25 feet (7.62 m) needs to be corrected.

## 6.2 PROCEDURAL ENHANCEMENTS

STE has taken a systematic approach to enhancing MDT procedures for collecting and analyzing road profile data. The systematic approach is based on developing the following items:

- Revising MT-422 "Method of Test for Surface Smoothness and Profile" (Appendix D),
- Developing a new Profiler Operations Manual (Appendix E), and
- Developing a new Quality Control / Quality Assurance Plan (Appendix F).

These documents have been developed and are discussed in the following paragraphs.

As discussed in Task A, the current MT-422 document is outdated and needed a revision based on the current MDT practices and also the findings of this project. STE has revised the MT-422 document.

The operations manual describes procedures to be followed when measuring pavement profiles using the ICC MDR 4080 / 4097 inertial profilers. STE has incorporated items from FHWA, ICC Operation Manual, and MT-422. The following items related to data collection have been covered: field testing, data collection, calibration of equipment, equipment maintenance, and record keeping. Each item has been developed (e.g., bulleted lists with screen captures) and comments inserted for operator's guidance.

A QC/QA plan was also developed for MDT. The purpose of the ride data collection QC/QA plan was to ensure that the procedures used by MDT in the collection and processing of ride data comply with all current MDT guidelines and result in the delivery of a quality data product. The QC/QA plan describes the following items: management responsibilities, staff requirements, required training, in-office procedures, field procedures, and in-house quality control reviews. The QC/QA plan also provides corrective actions when deficiencies are encountered and encourages actions that support continuous improvement.

## 6.3 SOFTWARE RECOMMENDATIONS

STE believes that MDT currently has a system that "works" properly. ICC software calculates the IRI and the ProScan module of the ICC software calculates the profile defect locations and size. As described in Task B, STE reviewed ProVAL 2.5 using MDT provided data sets thoroughly. The results of this analysis showed that ProVAL 2.5 does calculate IRI in the same manner as the ICC profiler software (i.e., using same algorithms) and that ProVAL 2.5 is an alternative to the ICC profiler software. However, similar to any other software in the development phase, ProVAL 2.5 also needs a series of improvements before it is ready to be a vital replacement for MDT's current system and fulfill MDT's analyzing needs. For example, although ProVAL 2.5 allows the user to create sections, it can be time consuming if there are a lot of unique length sections caused by excluded areas. Another example is the inability to automatically read markers from the data file and import into ProVAL 2.5.

As described in Task B, ProVAL 2.5 has the option of using the Localized Roughness (TEX-1001-S) Method (as discussed in AASHTO PP 51-03) for identifying a bump. STE recommends pilot testing the Localized Roughness (TEX-1001-S) method and compare results with MDT's current surface profile specification. The sliding base length and deviation threshold are set at 25 feet (7.62 m) and 0.15 inches (3.81 mm) in the Texas specification. MDT may have to modify these values to fit MDT's particular conditions. Once this is accomplished, MDT could fully transition to the Localized Roughness Method.

The Bumpfinder and Grinding Simulation modules of ProVAL 2.5 appear to be powerful and allow the engineer to strategize profile corrections, but there are drawbacks. MDT would have to define an IRI threshold, which may or may not identify a "bump" or "dip". Also, ProVAL 2.5 is still being evaluated and as with any new software there are still issues (e.g., loading files, processing files, and reporting results).

Another issue that was observed when evaluating the various software was the choice of units used. To simplify all software processing, STE recommends selecting one system of units (i.e., U.S. Customary), one method of section identification (i.e., start at 0 feet), and one direction of travel (i.e., all directions are positive). This will create consistency among operators as well as make it more consistent for engineers trying to locate sections with profile defects.

## 6.4 EXCLUSIONS & CONSTRAINTS

As discussed in Task B, STE investigated constraints of data collection along horizontal curves (i.e., 900 ft (274.32 m) radius taken from vendor operation manual). STE recommends that MDT continues using the 900 ft curvature of radius as the constraint along horizontal curves.

STE investigated whether 0.2 mile distance is enough for acceleration of profiler for climbing and passing lanes. STE recommends the following criterion: If possible, a profile run should have 0.75 mile (1.20 km) of run-up distance before testing any roadway, whether it is a climbing lane, passing lane, or ramp.

For bridge structures, STE has the following recommendations:

- STE recommends that if the bridge was not overlaid as part of the project, it should be excluded.
- For any bridge structure and/or approach slabs that have not been overlaid as part of the project, STE recommends measuring pavement sections up to 50 feet (15.24 m) from the structure and then resuming measurement 50 feet (15.24 m) past the structure. This applies to incentive and disincentive payments.
- STE has the following recommends the use of the same bump criteria (i.e., 0.4 inches (10 mm) in 25 feet (7.62 m)) used in the ride specification for excluded bridge deck sections.

# 7.0 TASK E. IMPLEMENTATION PLAN

Implementing the recommended improvements in Task D are the "products" of this project. The recommended improvements are those that are listed in the final report and approved by the MDT.

STE has put together the following list of products for implementation, which were a result of this project:

1. Revised MDT Ride Specification (Appendix C),
2. Revised MT-422 "Method of Test for Surface Smoothness and Profile" (Appendix D),
3. Profiler Operations Manual (Appendix E), and
4. QC/QA Plan (Appendix F).

The following paragraphs are the step by step activities *"suggested"* for the implementation of each product listed above:

## 7.1 IMPLEMENTING REVISED RIDE SPECIFICATION

It is suggested that MDT advertises the existence of a new draft specification to all its contractors and provides a copy of the specification on the MDT web page for review and download.

Within six months after the completion of this project, STE recommends MDT conduct a short one-day seminar for prospective contractors on how to follow the new ride specification during construction projects.

As part of the implementation process, MDT should monitor the new ride specification on a selected number of projects to assess its workability within the first year after the completion of this project. Then, final adjustments can be made if necessary.

## 7.2 IMPLEMENTING MT-422, PROFILER MANUAL, AND QC/QA PLAN

These documents are discussed together because the implementation of these products consists of one "plan".

In developing these documents, STE has attempted to be as specific as possible and to modify the documents to MDT conditions. Within six months after the completion of this project, MDT should conduct training seminars for office and field personnel involved in profiling activities.

Within nine months after the completion of this project all field and office personnel involved in profiling activities should have completed the training.

## 8.0 REFERENCES


1. Montana Department of Transportation (MDT), “Ride Specification for Flexible Pavement.” Revised 5-5-2003.

2. Montana Department of Transportation (MDT), “Methods of Sampling and Testing, MT-422, Method of Test for Surface Smoothness and Profile.” February 10, 2004.

3. Smith, K.L., Smith, K.D., Evans, L.D., Hoerner, T.E., Darter, M.I, and Woodstrom, J.H., “Smoothness Specifications for Pavements.” NCHRP Project 1-31, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., March 1997.

4. Perera, R.W. and Kohn, S.D., “Issues in Pavement Smoothness: A Summary Report.” NCHRP Project 20-51[1], National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., March 2002.

5. American Association State Highway and Transportation Officials (AASHTO), “2004 AASHTO Provisional Standard, MP11-03, Inertial Profiler.” June 2004.

6. American Association State Highway and Transportation Officials (AASHTO), “2004 AASHTO Provisional Standard, PP37-04, Determination of International Roughness Index (IRI) to Quantify Roughness of Pavements.” June 2004.

7. American Association State Highway and Transportation Officials (AASHTO), “2004 AASHTO Provisional Standard, PP49-03, Certification of Inertial Profiling Systems.” June 2004.

8. American Association State Highway and Transportation Officials (AASHTO), 2004 AASHTO Provisional Standard, PP50-03, “Operating Inertial Profilers and Evaluating Pavement Profiles”, June 2004.

9. American Association State Highway and Transportation Officials (AASHTO), “2004 AASHTO Provisional Standards, PP51-03, Pavement Ride Quality When Measured Using Inertial Profiling Systems.” June 2004.

10. Sayers, M.W. and Karamihas, S.M., “The Little Book of Profiling.” The University of Michigan Transportation Research Institute, September 1998.

11. Scofield, Larry A., Kalevaela, Sylvester, Anderson, Mary and Hossain, Asm. “A Half Century with the California Profilograph.” Arizona Department of Transportation (ADOT), February 1992.

12. RoadRuf User Reference Manual, UMTRI, October 1997.

13. Sayers, M.W. and Karamihas, S.M., "Interpretation of Road Roughness Profile Data." Federal Highway Administration, Contract DTFH 61-92-C00143. June 1996.

14. ProVAL website, http://www.transtecinc.com/proval/about.html.

15. Chang, George K., Dick, Jason C. and Robert O. Rasmussen, "ProVAL User's Guide." Version 2.50, Manual Revision: 1.08 (2.50), The Transtec Group, Inc.

# APPENDIX A.  STATE OF PRACTICE SURVEY

# RIDE SPECIFICATION SURVEY

(Return Date: October 15, 2004)

| | | |
|---|---|---|
| Agency: | | Date: |
| Name: | Title / Area of Responsibility: | |
| Phone Number: | Email: | |

## EQUIPMENT

Q1. What kind of equipment is used to collect ride data?

☐ High Speed Profiler ☐ Profilograph ☐ Straightedge Other ____________________

☐ Light Weight Profiler ☐ Mays Meter

Q2. Who is the manufacturer?

☐ Ames ☐ Cox ☐ KJ Law Engineering ☐ Rainhart

☐ California ☐ ICC ☐ McCracken Other ____________________

Q3. If applicable, what types of sensors are used?

☐ Ultrasonic ☐ Laser ☐ Infrared Other ____________________

Q4. If applicable, what is the number of sensors used? ____________________

Q5. If applicable, what is the number of accelerometers used? ____________________

Q6. If applicable, what is the sensor spacing used? ____________________

Q7. If applicable, how many crew members are in the vehicle while testing? ____________________

Q8. For Profile Index (PI), what blanking band is being used?

☐ 0.1 inch ☐ 0 inch Other: ____________________

☐ 0.2 inch ☐ Not Applicable

Q9. What method is used for positioning the blanking band?

☐ Alignment with previous section ☐ Computer selected best fit Other: ____________________

☐ Visual judgment ☐ Not Applicable

Q10. How is data processed and reduced?

☐ Computer software Other: ____________________

☐ Manually

Q10a. If applicable, what software is used?

☐ Vendor supplied Other: ____________________

☐ Agency developed

# RIDE SPECIFICATION SURVEY

Q10b. If applicable, what type of filter is applied to the data?

☐ Cox ☐ Moving Average

☐ Butterworth Other: ____________________

Q11. How often is equipment calibrated?

☐ Daily ☐ Yearly Other: ____________________

☐ Monthly ☐ Before each project

Q12. What methodology is used to calibrate equipment?

☐ Agency procedure Other: ____________________

☐ Vendor procedure

Q13. Rate the following properties for each type of equipment your agency uses on a scale of 1 (satisfied) to 5 (dissatisfied).

Q13a. For California profilograph:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Q13b. For Rainhart profilograph:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Q13c. For Ames profilograph:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Q13d. For Mays Meter:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Q13e. For high speed inertial profiler:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Q13f. For light weight inertial profiler:

Accuracy: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Repeatability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with same models: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Correlations with other equipment: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Durability: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Setup effort: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data collection rate: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Overall cost: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Expertise required: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Data reduction efforts: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
Grind identification: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

## SPECIFICATION

Q1. Does your agency currently have some form of initial ride quality specification?

☐ Yes Comment: ____________________

☐ No

Q2. Does your agency have a bump specification?

☐ Yes Comment: ____________________

☐ No

Q2a. What is the bump size (in) and base length (ft)? ____________________

Q3. What type of classification scheme does your agency use?

☐ Functional Class ☐ Pavement Type Other ____________________

☐ Posted Speed ☐ Traffic Volume

Q4. Which type of pavements is your ride specification applied to? (Mark all that apply)

☐ New AC ☐ New PCC ☐ AC / AC ☐ AC / PCC

Q5. For new AC, what kind of index is being used?

☐ Profile Index (PI) ☐ Mays Ride Number (MRN) Other ____________________

☐ International Roughness Index (IRI) ☐ Ride Quality Index (RQI)

☐ Not Applicable

Q5a. What units are used?

☐ in / mi Other ____________________

☐ m / km

Q5b. What is your data sampling method for ride quality data (e.g., entire project, random samples)? ______

Q5c. What is the test segment length (e.g., 0.1 mile, 500 feet, etc.)? ______

Q5d. What is your correction limit? ______

*If same index is being used for AC Overlay (AC & PCC), skip to Q8.*

Q6. For AC overlay AC, what kind of index is being used?

☐ Profile Index (PI) ☐ Mays Ride Number (MRN) ☐ Not Applicable

☐ International Roughness Index (IRI) ☐ Rolling Straightedge Other ______

Q6a. What units are used?

☐ in / mi

☐ m / km

Other ______

Q6b. What is your data sampling method for ride quality data (e.g., entire project, random samples)? ______

Q6c. What is the test segment length (e.g., 0.1 mile, 500 feet, etc.)? ______

Q6d. What is your correction limit? ______

Q7. For AC overlay PCC, what kind of index is being used?

☐ Profile Index (PI) ☐ Mays Ride Number (MRN) ☐ Not Applicable

☐ International Roughness Index (IRI) ☐ Rolling Straightedge Other ______

Q7a. What units are used?

☐ in / mi

☐ m / km

Other ______

Q7b. What is your data sampling method for ride quality data (e.g., entire project, random samples)? ______

Q7c. What is the test segment length (e.g., 0.1 mile, 500 feet, etc.)? ______

Q7d. What is your correction limit? ______________________________

Q8. Who is responsible for smoothness acceptance testing?

☐ Contractor

☐ Agency

Other ______________________________

Q9. How soon is acceptance testing performed after construction?

☐ Within 24 hours

☐ Within 48 hours

☐ Within 72 hours

☐ No time requirement / As soon as possible

Other ______________________________

Q10. For AC pavements, where is the longitudinal profile measurement taken?

☐ Right wheel path

☐ Left wheel path

☐ Both wheel paths

Other: ______________________________

Q10a. Which lane is testing performed in? (Travel lane, passing lane or both) ______________________________

Q11. What direction is testing performed?

☐ Bidirectional

☐ Direction of travel

☐ No requirement

Other: ______________________________

Q12. How many runs does your agency collect per project? ______________________________

## INCENTIVE / DISINCENTIVE

Q1. Does your agency have an incentive / disincentive program?

☐ Yes

☐ No

☐ Not Applicable

Comment: ______________________________

Q2. Is there a maximum acceptable roughness? ______________________________

Q3. How is your pay factor equation related to smoothness? ______________________________

Q4. What is the lower limit and upper limit of your incentive provisions? ______________________________

Q5. What is the lower limit and upper limit of your full pay provisions? ______________________________

# RIDE SPECIFICATION SURVEY

Q6. What is the lower limit and upper limit of your disincentive provisions? ____________________

Q7. How were your specified smoothness limits identified?

☐ Research and analysis ☐ Other agencies specifications Other: ____________________

☐ Engineering judgment ☐ AASHTO guide specification

Q8. How are your incentive / disincentive payment amounts determined (calculated)?

☐ Fixed amount (specify the unit): ____________________
☐ Portion of unit bid (specify the unit): ____________________
Other (specify): ____________________

## QC / QA

Q1. What QC/QA processes are in place for data collection? ____________________

Q1a. What is the acceptable range of speeds for your profiler equipment? ____________________

Q1b. How is data collection triggered for your profiler equipment (i.e., reflective stripes, cones, manually, etc.)? ____________________

Q1c. What types of profiler operational checks are performed? ____________________

Q1d. Where are profilers calibrated and / or certified? ____________________

Q1e. What type of training / certification do operators receive prior to operating a profiler? ____________________

Q2. What QC/QA processes are in place for data handling? ____________________

Q3. What QC/QA processes are in place for data analysis? ____________________

Q3a. What type of training / certification do analysts receive prior to processing / analyzing profile data? ____________________

Q4. Does contractor equipment have to undergo any calibration / verification testing? ____________________

## PROGRAMS

Q1. Does your agency collect ride data on the agency highway system for pavement management?

☐ Yes Comment: ____________________

☐ No

Q2. Does your agency collect ride data for HPMS?

☐ Yes Comment: ____________________

☐ No

# RIDE SPECIFICATION SURVEY

Q3. Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? ____________________

By how much? ____________________

And by when? ____________________

Q4. How does your agency feel about its current specifications?

☐ Adequate ☐ Functional but needs revision Other: ____________________

☐ Inadequate ☐ Not Applicable

Q5. What have been the results of having incentive / disincentive program on initial pavement smoothness?

☐ Records show significant smoother pavements ☐ Unknown ☐ Not Applicable

☐ No difference in pavement smoothness ☐ Too early to tell Comments: ____________________

Q6. What have been the results of having incentive / disincentive program on material / construction quality control?

☐ Records show better quality ☐ Too early to tell Comments: ____________________

☐ Perceived quality increase ☐ Unknown

☐ No difference ☐ Not Applicable

Q7. What have been the results of having incentive / disincentive program on overall cost to your agency?

☐ Significantly higher payments ☐ Too early to tell

☐ Significantly lower payments ☐ Unknown Comments: ____________________

☐ No difference ☐ Not Applicable

Q8. What are the issues facing your agency with its current ride specification? ____________________

Q9. Does agency or contractor collect profile data for acceptance? ____________________

Q10. Is the contractor allowed to correct any profile defects (i.e., grind) in order to receive incentive pay?

☐ Yes ☐ Not Applicable

☐ No Comment: ____________________

Q11. Is there a cap to how much money a contractor can earn in incentives and lose in disincentives? ____________________

Q12. What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? ____________________

## RETURN INFORMATION:

| | |
|---|---|
| Sierra Transportation Engineers, Inc.<br>1005 Terminal Way, Suite 125<br>Reno, NV 89502 | Receipt Date: |
| Attention: Sirous Alavi, Ph.D., P.E. | |
| Phone Number: 775-827-4400 | |
| Fax Number: 775-324-4407 | Email: sirous@ste-group.com |

# APPENDIX B.  SURVEY RESULTS

| | | | | | | EQUIPMENT | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Q1 | Q2 | Q3 |
| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | What kind of equipment is used to collect ride data? | Who is the manufacturer? | If applicable, what types of sensors are used? |
| Alabama | 29-Sep-04 | Scott W. George, P.E. | Pavement Management Engineer | 334-206-2309 | georges@dot.state.al.us | Profilograph | Any type of California type profilograph. | - |
| Alaska | 24-Nov-04 | Bruce Brunette, P.E.<br><br>Newton Bingham | Regional Materials Engineer, SE Region<br><br>Regional Materials Engineer, Central Region | 907-465-4198<br><br>907-269-6200 | bruce_brunette@dot.state.ak.us<br><br>newton_bingham@dot.state.ak.us | Light weight profiler<br>High speed profiler | Ames<br>Dynatest | Laser |
| Arizona | | | | | | | | |
| Arkansas | | | | | | | | |
| California | 28-Sep-04 | Peter Vacura | Chief of Office of Pavement Rehabilitation | 916-227-5845 | peter.vacura@dot.ca.gov | Profilograph | Other: QC performed by contractor by means of a "California" profilograph. Could be an Ames, McCracken, Cox, international pipe. | Other: Don't use inertial profilers in construction. |
| Colorado | 13-Oct-04 | Eric Prieve, P.E.<br>Steve Henry, EIT | Pavement Smoothness Program &<br>Pavement Management Program | 303-757-9269<br>303-757-9808 | eric.prieve@dot.state.co.us<br>stephen.henry@dot.state.co.us | High Speed Profiler<br>Profilograph<br><br>Other: Switching over to HSP (high speed profiler) in 2005. | ICC | Laser |

| | | | | | | EQUIPMENT | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Q1 | Q2 | Q3 |
| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | What kind of equipment is used to collect ride data? | Who is the manufacturer? | If applicable, what types of sensors are used? |
| Connecticut | 27-Sep-04 | Donald A. Larsen, P.E. | Trans. Supervising Engineer (Research) | 860-258-0301 | donald.larsen@po.state.ct.us | High Speed Profiler<br>Profilograph<br>Straightedge | ARAN Roadware Corporation - Canada<br>California | Laser |
| Delaware | | | | | | | | |
| DC | | | | | | | | |
| Florida | | | | | | | | |
| Georgia | 23-Sep-04 | Paul V. Eskew | Smoothness Test Engineer | 404-363-7588 | - | High Speed Profiler | ICC | Laser |
| Hawaii | | | | | | | | |
| Idaho | | | | | | | | |
| Illinois | 01-Oct-04 | LaDonna Rowden | Pavement Technology Engineer | 217-782-8582 | rowdenlr@dot.il.gov | Profilograph<br>Straightedge<br>Illinois uses a California type for new PCC and full-depth bituminous pavements. A straightedge is used on some bituminous overlays. | Ames<br>Cox<br>Both Illinois DOT and the contractors that construct roads use these types of profilographs. | Illinois does not currently allow inertial profilers for acceptance testing. |
| Indiana | | | | | | | | |
| Iowa | 01-Oct-04 | Kevin Jones | Testing Engineer | 515-239-1237 | - | High Speed Profiler<br>Light Weight Profiler<br>Profilograph<br>Straightedge | Ames<br>Cox<br>McCracken<br>ICC | Laser |
| Kansas | 07-Oct-04 | Bill Parcells | Pavement Surface Research Engineer | 785-291-3846 | billp@ksdot.org | High Speed Profiler<br>Light Weight Profiler<br>Profilograph<br>Straightedge | Ames<br>Cox<br>KJ Law Engineering<br>McCracken<br>ICC | Laser |
| Kentucky | 23-Sep-04 | J.S. Dade | Operations / Pavement | 502-564-4556 | John.Dade@ky.gov | High Speed Profiler | KJ Law Engineering<br>ICC | Laser<br>Infrared |

| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | EQUIPMENT<br>Q1<br>What kind of equipment is used to collect ride data? | Q2<br>Who is the manufacturer? | Q3<br>If applicable, what types of sensors are used? |
|---|---|---|---|---|---|---|---|---|
| Louisiana | 12-Oct-04 | Masood Rasoulian, P.E. | Sr. Pavement Research Engineer | 225-767-9112 | mrasouli@dotd.louisiana.gov | High Speed Profiler<br>Light Weight Profiler<br>Profilograph | Ames<br>ICC | Laser |
| Maine | | | | | | | | |
| Maryland | 10-Nov-04 | Timothy E. Smith, P.E. | Pavement & Geotechnical Division Chief | 410-321-3110 | tsmith2@sha.state.md.us | High Speed Profiler | ICC | Laser |
| Massachusetts | | | | | | | | |
| Michigan | 27-Sep-04 | Tom Hynes | Pavement Evaluation Engineer | 517-322-5711 | hynest@michigan.gov | High Speed Profiler<br>Light Weight Profiler<br>Profilograph<br>Straightedge | Other: Home built | Laser |
| Minnesota | 29-Sep-04 | Joe Thomas | Assistant Bituminous Engineer | 651-779-5619 | joe.thomas@dot.state.mn.us | High Speed Profiler<br>Light Weight Profiler<br>Profilograph | Ames<br>Cox<br>McCracken<br>Other: SSI | Laser |

| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | EQUIPMENT<br>Q1<br>What kind of equipment is used to collect ride data? | Q2<br>Who is the manufacturer? | Q3<br>If applicable, what types of sensors are used? |
|---|---|---|---|---|---|---|---|---|
| Mississippi | 24-Sep-04 | Randy Battey | State Research Engineer | 601-359-7650 | randyb@mdot.state.ms.us | High Speed Profiler<br>Light Weight Profiler<br>Profilograph<br>Straightedge | Ames<br>Cox<br>Rainhart<br>McCracken<br>ICC | Laser |
| Missouri | 06-Oct-04 | Dennis Bryant | Technical Support Engineer | 573-751-8608 | dennis.bryant@modot.mo.gov | Profilograph<br>Other: lightweight profilers on a case by case basis. | Ames<br>Other: MODOT machines are all Ames. Contractors may use any manufacturer. | - |
| Nebraska | | | | | | | | |
| Nevada | 01-Dec-04 | Bill Hoffman | Quality Assurance Engineer | 775-888-7226 | whoffman@dot.state.nv.us | Profilograph | California<br><br>Other: Contractor can use any manufacturer that meets specs. | N/A |
| New Hampshire | | | | | | | | |
| New Jersey | | | | | | | | |
| New Mexico | | | | | | | | |
| New York | 03-Oct-04 | Brad W. Allen, P.E. | CE-2 Pavement Surface Properties | 518-457-4580 | ballen@dot.state.ny.us | High Speed Profiler<br>Light Weight Profiler<br>Profilograph | Other: We do not approve based on manufacturer. We approve on a machine by machine basis. | Laser<br>Infrared |

| | | | | | | EQUIPMENT | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Q1 | Q2 | Q3 |
| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | What kind of equipment is used to collect ride data? | Who is the manufacturer? | If applicable, what types of sensors are used? |
| North Carolina | | | | | | | | |
| North Dakota | 13-Oct-04 | Ron Horner | Materials & Research Engineer | 701-328-6904 | rhorner@state.nd.us | Profilograph | Cox | - |
| Ohio | | | | | | | | |
| Oklahoma | | | | | | | | |
| Oregon | 14-Oct-04 | Mike Remily | Pavement Quality Engineer | 503-986-3120 | michael.d.remily@odot.state.or.us | Light Weight Profiler | Ames | Laser |
| Pennsylvania | 07-Oct-04 | Pat Gardiner | Quality Assurance-Construction | 717-787-4794 | jgardiner@state.pa.us | Light Weight Profiler | Ames<br>ICC<br>Other: SSI | Laser<br>Infrared |
| Puerto Rico | 30-Sep-04 | Miguel A. Estrella, EIT | Pavement Management | 787-798-3940 | mestrella@act.dtop.gov.pr | High Speed Profiler<br>Light Weight Profiler<br>Profilograph<br>Straightedge<br>Other: California type profilograph is used for final smoothness evaluation at project level. | ICC-Light weight profiler<br>McCracken-California type profilograph<br>Other: ARAN-Roadware for PMS purpose<br>Hi-low- ELE International | Laser |
| Rhode Island | | | | | | | | |
| South Carolina | | | | | | | | |
| South Dakota | 21-Oct-04 | Joshua Bench-Bresher | Transportation Engineer | 605-773-4464 | josh.bench-bresher@state.sd.us | Profilograph | Cox | - |
| Tennessee | 28-Sep-04 | Brian Egan | Materials & Testing- Field Operations | 615-350-4104 | Brian.Egan@state.tn.us | High Speed Profiler | ICC | Laser |

| | | | | | | EQUIPMENT | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Q1 | Q2 | Q3 |
| Agency | Date | Name | Title / Area of Responsibility | Phone Number | Email | What kind of equipment is used to collect ride data? | Who is the manufacturer? | If applicable, what types of sensors are used? |
| Texas | 08-Oct-04 | Magdy V. Mikhail | Assistant Director Flexible Pavement Branch<br>Construction Division | 512-506-5838 | mmikhai@dot.state.tx.us | High Speed Profiler<br>Light Weight Profiler | - | Laser |
| Utah | 02-Nov-04 | Murari Pradhan | Bituminous Engineer | 801-965-4521 | mpradhan@utah.gov | Profilograph | Cox<br>McCracken | Laser<br>Other: High speed profiler on trial for record. We have provisional spec. |
| Vermont | 01-Oct-04 | Mike Fowler | Pavement Management Engineer | 802-828-0160 | mike.fowler@state.vt.us | High Speed Profiler | Other: Dynatest | Laser |
| Virginia | 09-Nov-04 | Kevin McGhee | Research Engr./Asphalt | 434-293-1956 | kevin.mcghee@VDOT.Virginia.gov | High Speed Profiler<br>Profilograph<br><br>Other: Only a single profilograph project remains. All others are 'high-speed profiler' based. | ICC | Laser |
| Washington | 05-Oct-04 | Linda Pierce | State Pavement Engineer | 360-709-5470 | piercel@wsdot.wa.gov | High Speed Profiler | Other: Pathway services (high speed) | Laser |
| West Virginia | 08-Oct-04 | Chris Preston | HE3/QA for Smoothness | 304-558-3030 | cpreston@dot.state.wv.us | Light Weight Profiler<br>Mays Meter | Other: Dynatest-Model 6450 | Infrared |
| Wisconsin | | | | | | | | |
| Wyoming | 13-Oct-04 | Joel Dagnillo | Pavement Management | 307-777-4722 | joel.dagnillo@state.wy.us | High Speed Profiler | ICC | Laser |

| | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|
| Agency | If applicable, what is the number of sensors used? | If applicable, what is the number of accelerometers used? | If applicable, what is the sensor spacing used? | If applicable, how many crew members are in the vehicle while testing? | For Profile Index (PI) what blanking band is being used? | What method is used for positioning the blanking band? |
| Alabama | - | - | - | - | 0 inch | Computer selected best fit |
| Alaska | 1<br>7 | 1<br>3 | NA<br>Center line of front tires on Expedition & 58" | 1 | 0.2 inch | Computer selected best fit |
| Arizona | | | | | | |
| Arkansas | | | | | | |
| California | - | - | - | - | 0 inch | Computer selected best fit |
| Colorado | 2 | 2 | 72 inches | 1 | 0.1 inch | Computer selected best fit |

| | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|
| Agency | If applicable, what is the number of sensors used? | If applicable, what is the number of accelerometers used? | If applicable, what is the sensor spacing used? | If applicable, how many crew members are in the vehicle while testing? | For Profile Index (PI) what blanking band is being used? | What method is used for positioning the blanking band? |
| Connecticut | 2 | 1 | One in each wheel path | 2 | 0 inch | Not applicable |
| Delaware | | | | | | |
| DC | | | | | | |
| Florida | | | | | | |
| Georgia | 2 | 2 | There is one laser on either end of | One | Not applicable | Not applicable |
| Hawaii | | | | | | |
| Idaho | | | | | | |
| Illinois | - | - | - | - | 0 inch<br>0.2 inch<br>The 0 inch blanking band is used on interstates and selected non-interstate routes; the 0.20 inch blanking band is used for other PCC and full-depth bituminous pavements. | Computer selected<br>Visual judgment<br>0.2 inch blanking bands can be either computer selected (ProScan) or visual. 0.0 inch blanking bands must be computer selected. |
| Indiana | | | | | | |
| Iowa | 1, 2, 3 | 1, 2 | NA | 1, 2 | 0.2 inch | Computer selected best fit<br>Visual judgment |
| Kansas | HSP 3<br>Profiler 1 or 2 | 2 | 33 inches<br>66 inches between wheel paths | 2 | 0 inch | Computer selected |
| Kentucky | 2 | 2 | 66" | 1 | - | - |

| | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|
| Agency | If applicable, what is the number of sensors used? | If applicable, what is the number of accelerometers used? | If applicable, what is the sensor spacing used? | If applicable, how many crew members are in the vehicle while testing? | For Profile Index (PI) what blanking band is being used? | What method is used for positioning the blanking band? |
| Louisiana | 3 lasers, 1 in each wp, one in center for reference<br>light weight profilers have either one or two. | Two accelerometers | 61 inches for high speed, varies for lightweight ones. | Usually, one for rural areas, and two in crowded urban areas. | 0.2 inches | Computer selected best fit for automated systems, visual adjustment for manually produced traces. |
| Maine | | | | | | |
| Maryland | 2 | 2 | 67-69 in | 2 | Not applicable | Not applicable |
| Massachusetts | | | | | | |
| Michigan | 1 on light weight<br>2 on high speed | 1 on light weight<br>2 on high speed | - | 1 on light weight<br>2 on high speed | 0 inch | Computer selected best fit |
| Minnesota | 1 | 1 | NA | 1 or 2 | 0.2 inch | Computer selected best fit<br><br>Other: Offset linear regression |

| | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|
| Agency | If applicable, what is the number of sensors used? | If applicable, what is the number of accelerometers used? | If applicable, what is the sensor spacing used? | If applicable, how many crew members are in the vehicle while testing? | For Profile Index (PI) what blanking band is being used? | What method is used for positioning the blanking band? |
| Mississippi | 1 or 2 | 1 or 2 | 34.5" | 1 or 2 | 0 inch | Alignment with previous section |
| Missouri | - | - | - | - | 0 inch | Computer selected best fit |
| Nebraska | | | | | | |
| Nevada | N/A | N/A | N/A | N/A | 0.2 inch | Visual judgment<br>Computer selected best fit<br><br>Other: Initial run by contractor, rolls checked visually after they're submitted to resident engineer. |
| New Hampshire | | | | | | |
| New Jersey | | | | | | |
| New Mexico | | | | | | |
| New York | One | Not directly specified. | ? | Not specified- usually one. | PCC Only<br>0.2 inch<br><br>HMA<br>IRI | Computer selected best fit |

| Agency | Q4<br>If applicable, what is the number of sensors used? | Q5<br>If applicable, what is the number of accelerometers used? | Q6<br>If applicable, what is the sensor spacing used? | Q7<br>If applicable, how many crew members are in the vehicle while testing? | Q8<br>For Profile Index (PI) what blanking band is being used? | Q9<br>What method is used for positioning the blanking band? |
|---|---|---|---|---|---|---|
| North Carolina | | | | | | |
| North Dakota | - | - | - | - | 0 inch | Computer selected best fit |
| Ohio | | | | | | |
| Oklahoma | | | | | | |
| Oregon | 1 | 1 | - | - | 0.2 inch | Computer selected best fit |
| Pennsylvania | - | - | - | - | Not applicable | Not applicable |
| Puerto Rico | 2 for ICC LWP | 2 for ICC LWP | - | 1 for ICC LWP | 0.2 inch | Computer selected best fit |
| Rhode Island | | | | | | |
| South Carolina | | | | | | |
| South Dakota | - | - | - | - | 0.2 inch<br>0 inch | Computer selected best fit |
| Tennessee | 2 | 2 | wheel paths | 1 | 0.1 inch<br>Rainhart on PCCP & bridge decks | Computer selected best fit |

| | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|
| Agency | If applicable, what is the number of sensors used? | If applicable, what is the number of accelerometers used? | If applicable, what is the sensor spacing used? | If applicable, how many crew members are in the vehicle while testing? | For Profile Index (PI) what blanking band is being used? | What method is used for positioning the blanking band? |
| Texas | - | - | - | - | Other: In our old specification we used 0 inch blanking band. | - |
| Utah | Laser | 2 | Standard according to ASTM. | - | 0.2 inch | Computer selected best fit |
| Vermont | 2<br>Total of 9 sensors but only 2 are used for ride | 2 | 66 inches wheel path | 2 | Not applicable | Not applicable |
| Virginia | 2 (left & right wheel path)+1(center)<br>3 | 2 | 69" | 2 routinely | 0.2 inch<br>Other: One project remaining | Computer selected best fit |
| Washington | 3 | 2 | 2 | 2 | Other: WSDOT does not calculate PI | Not applicable |
| West Virginia | 2 | 2 | 69 inches | 2 | Not applicable | Not applicable |
| Wisconsin | | | | | | |
| Wyoming | 2 | 2 | one over each wheel path | 1 | 0.2 inch | Computer selected best fit |

| Agency | Q10<br>How is data processed and reduced? | Q10a<br>If applicable, what software is used? | Q10b<br>If applicable, what type of filter is applied to the data? | Q11<br>How often is equipment calibrated? | Q12<br>What methodology is used to calibrate equipment? |
|---|---|---|---|---|---|
| Alabama | Computer software | ProScan | Moving average | Before each project<br>Before each analysis | Agency procedure |
| Alaska | Computer software | Vendor supplied | Butterworth | Before each use<br><br>Yearly<br>Other: Calibrated annually, checked before each measurement. | Vendor procedure<br><br>Other:ASTM E950 class 1 expected. |
| Arizona | | | | | |
| Arkansas | | | | | |
| California | Computer software | Vendor supplied | Butterworth 3rd order | Before each project | Agency procedure |
| Colorado | Computer software | Vender supplied | - | Daily | Agency procedure<br>Vendor procedure |

| | Q10 | Q10a | Q10b | Q11 | Q12 |
|---|---|---|---|---|---|
| Agency | How is data processed and reduced? | If applicable, what software is used? | If applicable, what type of filter is applied to the data? | How often is equipment calibrated? | What methodology is used to calibrate equipment? |
| Connecticut | Computer software<br>IRI calculated by software. | Agency developed | Butterworth<br>1/4 car simulation | Monthly<br>Control sites run monthly. | Agency procedure<br>Vendor procedure<br>Vendor procedure used on agency-selected control sites. |
| Delaware | | | | | |
| DC | | | | | |
| Florida | | | | | |
| Georgia | Computer software | Vendor supplied | Butterworth | Daily<br>Before each project | Vendor procedure |
| Hawaii | | | | | |
| Idaho | | | | | |
| Illinois | Computer Software<br>Manually<br>See Q9. | Vendor Supplied<br>ProScan | Butterworth | Before each project<br>May vary from project to project. Vertical and horizontal calibration should be performed each time before testing. | Agency procedure<br>Calibration similar to method provided in California Test Method 526. |
| Indiana | | | | | |
| Iowa | Computer Software<br>Manually | Vendor Supplied | Butterworth | Yearly | Agency procedure<br>Vendor procedure |
| Kansas | Computer software | Vendor supplied<br>Other: ProScan | Moving average | Yearly | Agency procedure<br>Vendor procedure |
| Kentucky | - | - | Moving average | Monthly | Vendor procedure |

| Agency | Q10<br>How is data processed and reduced? | Q10a<br>If applicable, what software is used? | Q10b<br>If applicable, what type of filter is applied to the data? | Q11<br>How often is equipment calibrated? | Q12<br>What methodology is used to calibrate equipment? |
|---|---|---|---|---|---|
| Louisiana | Computer software for automated systems and manual methods for paper traces. | Vendor supplied (ICC, ProVAL is being considered for standard software currently by department). | Butterworth for PI, Moving average for IRI | Yearly for contractors' certification approval, before each project (accelerometers calibration). | Agency procedure |
| Maine | | | | | |
| Maryland | Computer software | Vendor supplied | Moving average | Monthly<br>Before each project | Agency procedure<br>Vendor procedure |
| Massachusetts | | | | | |
| Michigan | Computer software | Agency developed | Butterworth | Yearly<br>Checked more often | Agency procedure |
| Minnesota | Computer software | Vendor supplied | Butterworth | Yearly<br>Before each project<br><br>Certification yearly, however before each project, the device is required to do its pre-check. | Agency procedure |

| | Q10 | Q10a | Q10b | Q11 | Q12 |
|---|---|---|---|---|---|
| Agency | How is data processed and reduced? | If applicable, what software is used? | If applicable, what type of filter is applied to the data? | How often is equipment calibrated? | What methodology is used to calibrate equipment? |
| Mississippi | Computer software<br>Manually | Vendor supplied | Butterworth | Before each project<br>Certify each 6 months | Agency procedure |
| Missouri | Computer software | Vendor supplied | - | Yearly | Agency procedure |
| Nebraska | | | | | |
| Nevada | Computer software | Vendor supplied | Unknown | Before each project | Agency procedure |
| New Hampshire | | | | | |
| New Jersey | | | | | |
| New Mexico | | | | | |
| New York | Computer software<br>Manually<br><br>Selected by contractor | Other: selected by contractor | Butterworth | Daily for inertial profilers-HMA<br>Before each project for CA profilographs-PCC | Vendor procedure |

| | Q10 | Q10a | Q10b | Q11 | Q12 |
|---|---|---|---|---|---|
| Agency | How is data processed and reduced? | If applicable, what software is used? | If applicable, what type of filter is applied to the data? | How often is equipment calibrated? | What methodology is used to calibrate equipment? |
| North Carolina | | | | | |
| North Dakota | Computer software | Vendor Supplied | Butterworth | Yearly | Agency procedure |
| Ohio | | | | | |
| Oklahoma | | | | | |
| Oregon | Computer software | Vendor Supplied | Moving average | Before each project | Vendor procedure |
| Pennsylvania | Computer software | Vendor Supplied | - | Daily<br>Other: Yearly state validation of equipment performance | Vendor procedure |
| Puerto Rico | Computer software | Vendor Supplied<br>Other: MS Access, DB creator view-ARAN<br>Win-report-LWP | Moving average | Monthly-ARAN<br>Before each project-LWP, profilograph | Vendor procedure |
| Rhode Island | | | | | |
| South Carolina | | | | | |
| South Dakota | Computer software | Vendor Supplied | Butterworth | Before each project | Agency procedure |
| Tennessee | Computer software | Vendor Supplied | - | Daily<br>Every quarter look at reproducibility & repeatability between 5 profilers used in the state. | Agency procedure |

| | Q10 | Q10a | Q10b | Q11 | Q12 |
|---|---|---|---|---|---|
| Agency | How is data processed and reduced? | If applicable, what software is used? | If applicable, what type of filter is applied to the data? | How often is equipment calibrated? | What methodology is used to calibrate equipment? |
| Texas | Computer software | Agency developed | - | Yearly | Agency procedure<br>Other: TTI / Texas A&M have a center for certifying equipment & operators. |
| Utah | Computer software | Vendor Supplied | Cox<br>Butterworth | Yearly<br>Other: Dept. verifies the calibration for bump location & bump height & PI. Check physical condition of the equipment. | Agency procedure |
| Vermont | Computer software | Vendor Supplied | N/A<br>- | Yearly | Vendor procedure |
| Virginia | Computer software | Vendor Supplied | Other: | Other: Weekly<br><br>Note: Profilers are not calibrated, can only be validated. | Agency procedure |
| Washington | Computer software | Vendor Supplied | Other: High pass filer with a wavelength of 300'. | Yearly<br>Other: Or when verification tests warrant. | Vendor procedure |
| West Virginia | Computer software | Vendor Supplied | N/A | Before each project | Vendor procedure |
| Wisconsin | | | | | |
| Wyoming | Computer software | Vendor Supplied | Moving average | Other: Accelerometers before each test, DMI monthly, Bounce test monthly, height sensors every 3 months. | Agency procedure |

Rated from 1 (satisfied) to 5 (dissatisfied)

1) Accuracy
2) Repeatability
3) Correlations with same models
4) Correlations with other equipment
5) Durability
6) Setup effort
7) Data collection rate
8) Overall cost
9) Expertise required
10) Data reduction efforts
11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | | Q13b For Rainhart profilograph | | | | | | | | | | | Q13c For Ames profilograph | | | | | | | | | | | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Alabama | 1 | 1 | - | - | 1 | 2 | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Alaska | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Arizona | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arkansas | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| California | 1 | 1 | 2 | - | 1 | 2 | 2 | 1 | 2 | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Colorado | 3 | 3 | 4 | 4 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Rated from 1 (satisfied) to 5 (dissatisfied) | 1) Accuracy | 2) Repeatability | 3) Correlations with same models | 4) Correlations with other equipment | 5) Durability | 6) Setup effort | 7) Data collection rate | 8) Overall cost | 9) Expertise required | 10) Data reduction efforts | 11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | | Q13b For Rainhart profilograph | | | | | | | | | | | Q13c For Ames profilograph | | | | | | | | | | | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Connecticut | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Delaware | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DC | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Florida | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Georgia | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Hawaii | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Idaho | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Illinois | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Indiana | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Iowa | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Kansas | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Kentucky | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Rated from 1 (satisfied) to 5 (dissatisfied)

1) Accuracy
2) Repeatability
3) Correlations with same models
4) Correlations with other equipment
5) Durability
6) Setup effort
7) Data collection rate
8) Overall cost
9) Expertise required
10) Data reduction efforts
11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | | Q13b For Rainhart profilograph | | | | | | | | | | | Q13c For Ames profilograph | | | | | | | | | | | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Louisiana | 3 | 3 | 3 | 3 | 4 | 5 | 5 | 2 | 3 | 4 | 4 | - | - | - | - | - | - | - | - | - | - | - | 3 | 3 | 3 | 3 | 4 | 5 | 5 | 2 | 3 | 4 | 4 | - | - | - | - | - | - | - | - | - | - | - |
| Maine | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maryland | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Massachusetts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Michigan | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Minnesota | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - |

Rated from 1 (satisfied) to 5 (dissatisfied)

1) Accuracy
2) Repeatability
3) Correlations with same models
4) Correlations with other equipment
5) Durability
6) Setup effort
7) Data collection rate
8) Overall cost
9) Expertise required
10) Data reduction efforts
11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | | Q13b For Rainhart profilograph | | | | | | | | | | | Q13c For Ames profilograph | | | | | | | | | | | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Mississippi | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Missouri | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Nebraska | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nevada | 2 | 1 | 2 | 2 | 2 | 4 | 4 | 2 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| New Hampshire | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New Jersey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New Mexico | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| New York | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Rated from 1 (satisfied) to 5 (dissatisfied)

1) Accuracy
2) Repeatability
3) Correlations with same models
4) Correlations with other equipment
5) Durability
6) Setup effort
7) Data collection rate
8) Overall cost
9) Expertise required
10) Data reduction efforts
11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | | Q13b For Rainhart profilograph | | | | | | | | | | | Q13c For Ames profilograph | | | | | | | | | | | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| North Carolina | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| North Dakota | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ohio | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oklahoma | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oregon | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pennsylvania | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Puerto Rico | 2 | 2 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 4 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Rhode Island | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| South Carolina | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| South Dakota | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 3 | 2 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tennessee | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 |

Rated from 1 (satisfied) to 5 (dissatisfied)

1) Accuracy 2) Repeatability 3) Correlations with same models 4) Correlations with other equipment 5) Durability 6) Setup effort 7) Data collection rate 8) Overall cost 9) Expertise required 10) Data reduction efforts 11) Grind identification

| | Q13a For California profilograph | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Texas | - | - | - | - | - | - | - | - | - | - | - |
| Utah | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| Vermont | - | - | - | - | - | - | - | - | - | - | - |
| Virginia | 4 | 3 | 3 | 4 | 4 | 4 | 5 | 3 | 4 | 4 | 2 |
| Washington | - | - | - | - | - | - | - | - | - | - | - |
| West Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Wisconsin | | | | | | | | | | | |
| Wyoming | - | - | - | - | - | - | - | - | - | - | - |

| | Q13b For Rainhart profilograph | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Texas | - | - | - | - | - | - | - | - | - | - | - |
| Utah | - | - | - | - | - | - | - | - | - | - | - |
| Vermont | - | - | - | - | - | - | - | - | - | - | - |
| Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Washington | - | - | - | - | - | - | - | - | - | - | - |
| West Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Wisconsin | | | | | | | | | | | |
| Wyoming | - | - | - | - | - | - | - | - | - | - | - |

| | Q13c For Ames profilograph | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Texas | - | - | - | - | - | - | - | - | - | - | - |
| Utah | - | - | - | - | - | - | - | - | - | - | - |
| Vermont | - | - | - | - | - | - | - | - | - | - | - |
| Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Washington | - | - | - | - | - | - | - | - | - | - | - |
| West Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Wisconsin | | | | | | | | | | | |
| Wyoming | - | - | - | - | - | - | - | - | - | - | - |

| | Q13d For Mays Meter | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Texas | - | - | - | - | - | - | - | - | - | - | - |
| Utah | - | - | - | - | - | - | - | - | - | - | - |
| Vermont | - | - | - | - | - | - | - | - | - | - | - |
| Virginia | - | - | - | - | - | - | - | - | - | - | - |
| Washington | - | - | - | - | - | - | - | - | - | - | - |
| West Virginia | 3 | 4 | - | 3 | 2 | 1 | 1 | 2 | 1 | 1 | - |
| Wisconsin | | | | | | | | | | | |
| Wyoming | - | - | - | - | - | - | - | - | - | - | - |

| Agency | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Alabama | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Alaska | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Arizona | | | | | | | | | | | | | | | | | | | | | | |
| Arkansas | | | | | | | | | | | | | | | | | | | | | | |
| California | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Colorado | 1 | 2 | - | - | - | 1 | 1 | - | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - |

| | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Connecticut | 3 | 1 | 3 | 5 | 1 | 3 | 2 | 4 | 3 | 1 | 5 | - | - | - | - | - | - | - | - | - | - | - |
| Delaware | | | | | | | | | | | | | | | | | | | | | | |
| DC | | | | | | | | | | | | | | | | | | | | | | |
| Florida | | | | | | | | | | | | | | | | | | | | | | |
| Georgia | 1 | 1 | 2 | 3 | 2 | 1 | 1 | 3 | 1 | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - |
| Hawaii | | | | | | | | | | | | | | | | | | | | | | |
| Idaho | | | | | | | | | | | | | | | | | | | | | | |
| Illinois | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Indiana | | | | | | | | | | | | | | | | | | | | | | |
| Iowa | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Kansas | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 4 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kentucky | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | - | - | - | - | - | - | - | - | - | - | - |

| | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Louisiana | 1 | 1 | - | 2 | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 2 |
| Maine | | | | | | | | | | | | | | | | | | | | | | |
| Maryland | 3 | 3 | 2 | 4 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | - | - | - | - | - | - | - | - | - | - | - |
| Massachusetts | | | | | | | | | | | | | | | | | | | | | | |
| Michigan | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 3 | 2 | 1 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 4 | 3 | 3 | 2 | 2 |
| Minnesota | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 1 |

| | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Mississippi | 2 | 2 | 2 | 2 | 3 | 2 | 1 | 4 | 4 | 2 | 4 | 2 | 3 | 3 | 3 | 2 | 2 | 1 | 4 | 4 | 2 | 3 |
| Missouri | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Nebraska | | | | | | | | | | | | | | | | | | | | | | |
| Nevada | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| New Hampshire | | | | | | | | | | | | | | | | | | | | | | |
| New Jersey | | | | | | | | | | | | | | | | | | | | | | |
| New Mexico | | | | | | | | | | | | | | | | | | | | | | |
| New York | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agency | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| North Carolina | | | | | | | | | | | | | | | | | | | | | | |
| North Dakota | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ohio | | | | | | | | | | | | | | | | | | | | | | |
| Oklahoma | | | | | | | | | | | | | | | | | | | | | | |
| Oregon | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 |
| Pennsylvania | - | - | - | - | - | - | - | - | - | - | - | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 1 |
| Puerto Rico | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| Rhode Island | | | | | | | | | | | | | | | | | | | | | | |
| South Carolina | | | | | | | | | | | | | | | | | | | | | | |
| South Dakota | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tennessee | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |

| Agency | Q13e For high speed inertial profiler | | | | | | | | | | | Q13f For light weight inertial profiler | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Texas | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Utah | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Vermont | 2 | 1 | 1 | 1 | 2 | 4 | 2 | 4 | 1 | 3 | 2 | - | - | - | - | - | - | - | - | - | - | - |
| Virginia | 2 | 1 | 1 | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 4 | - | - | - | - | - | - | - | - | - | - | - |
| Washington | 1 | 1 | - | 2 | 2 | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| West Virginia | - | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 3 | 1 | 1 | 1 |
| Wisconsin | | | | | | | | | | | | | | | | | | | | | | |
| Wyoming | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 3 | 3 | 1 | - | - | - | - | - | - | - | - | - | - | - |

| | SPECIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| Alabama | Yes | No | - | Posted speed | All | Profile Index (PI) | in/mi |
| Alaska | Yes<br><br>Yes<br>PRI = 1"/mi job average 5% or 10% bonus<br>PRI = 7"/mi job average No bonus, No penalty | Yes<br><br>Yes<br>1/4" in 16' (straight edge) | >15"/mi in any 0.1 mile increment<br><br>- | Pavement type<br><br>- | New AC<br><br>New AC<br>AC/AC | Profile Index (PI) | in/mi<br><br>in/mi<br>Other: Based on Project units |
| Arizona | | | | | | | |
| Arkansas | | | | | | | |
| California | Yes | Yes | 7.5 mm in 7.5 m | Pavement type | All | Profile Index (PI) | m/km |
| Colorado | Yes<br>Profilograph based specification.<br>Will pilot HSP specification in 2005. | Yes | 0.3" in 25' | Functional class | All | Profile Index (PI) | in/mi<br>m/km<br>Other: Depends if the project is in metric or english units. |

| | SPECIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| Connecticut | Yes<br>Special provision used only on selected HMA overlays. There are also ranges of acceptable PI for PCC pavements. | Yes<br>(see attached specification) | 0.25" per 10' for flexible<br>0.5" per 25' for rigid | Pavement type | All | Profile Index (PI)<br>International Roughness Index (IRI) | m/km |
| Delaware | | | | | | | |
| DC | | | | | | | |
| Florida | | | | | | | |
| Georgia | Yes | No | - | Pavement type | All | International Roughness Index (IRI) | mm/km |
| Hawaii | | | | | | | |
| Idaho | | | | | | | |
| Illinois | Yes<br>IDOT has a 0.20 inch blanking band with incentive and disincentives for the standard specifications; the 0.00 inch blanking band is used on interstates and selected non-interstates through a special provision with incentive and disincentives. | Yes | 0.30" in 25' | All state routes use the smoothness requirements either through the standard specifications or special provision as listed earlier. | All | Profile Index (PI) | in/mi<br>m/km |
| Indiana | | | | | | | |
| Iowa | Yes | Yes | 1/2" in 25'<br>1/8" in 10' | Functional class<br>Pavement type<br>Posted speed | All | Profile Index (PI) | in/mi<br>Other: mm/km |
| Kansas | Yes | Yes | Asphalt<br>0.4" in 25'<br><br>PCC<br>0.3" in 25' | - | All | Profile Index (PI) | in/mi<br>m/km<br>Other: mm/km |
| Kentucky | Yes<br>Separate ride specifications for AC & PCC pavements. | No | - | All | All | International Roughness Index (IRI) | in/mi |

| | SPECIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| Louisiana | IRI specification for AC pavements have been implemented on pilot projects. IRI specifications for PCCP are being developed. | Yes, >0.3"{ needs correction (based on PI traces) | 0.3" on 25' base length (based on PI traces) | Pavement type (AC or PCCP)<br>Other: Posted speed for PCCP only | All | Profile Index (PI) being phased out<br>International Roughness Index (IRI) | in/mi |
| Maine | | | | | | | |
| Maryland | Yes | Yes<br>Bumps are addressed as localized roughness; sections with excessively high IRI (called defect sections) are either corrected or have a disincentive applied in addition to overall ride incentive/disincentive. | IRI>= 120-200 in/mile in a 25 ft long section | Functional class | All | International Roughness Index (IRI) | in/mi |
| Massachusetts | | | | | | | |
| Michigan | Yes<br>Inertial profiler spec since 1977 | Yes | Currently California profilograph model 0.3" in 25 ' | Posted speed | All | Profile Index (PI)<br>Ride Quality Index (RQI)<br>Contractors choice of PI or RQI. Most bituminous contractors choose RQI. | in/mi for PI<br><br>RQI is unit less |
| Minnesota | Yes | Yes | 0.4" in 25' | Pavement type | All | Profile Index (PI) | in/mi |

| | *SPECIFICATION* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| Mississippi | Yes | Yes | 0.4" per 25' for flexible<br>0.3" per 25' for rigid | Pavement type | All | Profile Index (PI) | in/mi<br>m/km |
| Missouri | Yes | Yes | 0.4" in 25' | Posted speed | All | Profile Index (PI) | in/mi |
| Nebraska | | | | | | | |
| Nevada | Yes | Yes | 3/10" in 25' | Functional class | All | Profile Index (PI) | in/mi |
| New Hampshire | | | | | | | |
| New Jersey | | | | | | | |
| New Mexico | | | | | | | |
| New York | Yes<br>HMA spec is based on IRI.<br>PCC spec is based on PI. | Yes | 5 mm measured with 5 m straightedge. | Other: Classification? | All | International Roughness Index (IRI) | m/km |

| | SPECIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| North Carolina | | | | | | | |
| North Dakota | No | Yes | 0.3" in 25' | Pavement type<br>Posted Speed<br>Other: PCC Pavements, >40mph-<1/8" in 10', <40 mph-<1/4" in 10' | New PCC | Not applicable | - |
| Ohio | | | | | | | |
| Oklahoma | | | | | | | |
| Oregon | Yes | Yes | 3/8" in 25' (9 mm, 7.62m) | Posted speed | All | Profile Index (PI) | m/km |
| Pennsylvania | Yes | No<br>We eliminated the 0.4" in 25' bump but are considering a new bump criteria. | - | Functional class<br>Pavement type<br>Posted speed<br>Traffic volume | All | International Roughness Index (IRI) | in/mi<br>m/km |
| Puerto Rico | Yes<br>Attached specifications 410: Hot Plant-Mix Bituminous Pavement Smoothness, 510: PCC and 680: Bridges. | Yes | Bump size =0.4"<br>Base length=25' | Pavement type | All | Profile Index (PI) | in/mi |
| Rhode Island | | | Bituminous Pavement<br>0.25" in 10' | | | | |
| South Carolina | | | | | | | |
| South Dakota | Yes | Yes | 0.3" in 25' | - | New PCC | - | - |
| Tennessee | Yes<br>Only for state route resurfacing w/thin lifts. | Yes | For bituminous pavements = 1/4" with 12' straightedge.<br>For PCC pavements = 1/8" with 12' straightedge. | Functional class<br>Pavement type<br>Posted speed<br>Have different requirements based on pavement types & classifications and some low speed w/no or less requirements. | All | Half Car IRI | in/mi |

| | SPECIFICATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q2a | Q3 | Q4 | Q5 | Q5a |
| Agency | Does your agency currently have some form of initial ride quality specification? | Does your agency have a bump specification? | What is the bump size and base length? | What type of classification scheme does your agency use? | Which type of pavements is your ride specification applied to?<br>New AC, New PCC, AC/AC, AC/PCC | For new AC, what kind of index is being used? | What units are used? |
| Texas | Yes | Yes | - | Other: A combination of all what is listed. | All | International Roughness Index (IRI) | in/mi |
| Utah | Yes<br>Special provisional specification for the regions to try Dept. profiler. | Yes<br>0.3" | 0.3" in 25' | Functional class<br>Pavement type<br>Traffic volume<br>Other: Flexible & rigid pavements | All | Profile Index (PI)<br>Other: IRI for special provision spec. | in/mi |
| Vermont | Yes | No | - | Functional class | New AC<br>AC/AC<br>AC/PCC | International Roughness Index (IRI) | in/mi<br>m/km |
| Virginia | Yes<br>IRI based. | No | - | Posted speed<br>Pavement type | All | International Roughness Index (IRI) | in/mi |
| Washington | Currently working on ride spec which should be completed by end of 2004. | Yes | - | Functional class<br>Pavement type | All | International Roughness Index (IRI) | in/mi |
| West Virginia | Yes | No | - | Other: New pavement thickness | All | Mays Ride Number (MRN)<br><br>Although WV mentioned MRN, their spec refers to in/mi units, which indicates they have moved to IRI. | in/mi<br>m/km |
| Wisconsin | | | | | | | |
| Wyoming | Yes<br>Bonuses are given for good ride quality, deductions given for poor ride quality. This based on developed curve. | Yes<br>Greater than 40 mph-0.4" in 25' or less<br><br>Less than or equal to 40 mph-0.7" in 25' or less | -<br>Greater than 40 mph-0.4" in 25' or less<br><br>Less than or equal to 40 mph-0.7" in 25' or less | Functional class | New AC<br>AC/AC<br>AC/PCC | International Roughness Index (IRI) | in/mi<br>m/km<br>Other: Both are used at times. Usually in/mi. |

| | Q5b | Q5c | Q5d | Q6 | Q6a | Q6b | Q6c | Q6d |
|---|---|---|---|---|---|---|---|---|
| Agency | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | For AC overlay AC what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? |
| Alabama | Entire project | 0.1 mile | 50 in/mi | - | - | - | - | - |
| Alaska | Entire project<br><br>Average of all lanes, average L&R wheel paths, for entire project | 0.1 mile<br><br>entire project, all lanes | Any segment exceeding 15"/mi for any 0.1 mile segment must be corrected or a penalty will be assessed.<br><br>- | Profile Index (PI)<br><br>- | in/mi<br><br>- | Entire project<br><br>- | 0.1 mile<br><br>- | Same as new AC<br><br>- |
| Arizona | | | | | | | | |
| Arkansas | | | | | | | | |
| California | Entire project | 0.1 km | 48 mm / 0.1 km | Profile Index (PI) | m/km | Entire project | 0.1 km | 64 mm / 0.1 km |
| Colorado | Entire project | 0.1 mile | PI=24.1 in/mi for interstate<br><br>PI=28.1 in/mi for non-interstate with speed limit over 45 mph<br><br>PI=34.1 in/mi for all others | Profile Index (PI) | - | - | - | - |

| | Q5b | Q5c | Q5d | Q6 | Q6a | Q6b | Q6c | Q6d |
|---|---|---|---|---|---|---|---|---|
| Agency | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | For AC overlay AC what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? |
| Connecticut | All mainline travel lanes and turning roadways must be tested. Each 160 meters is a segment. | 160 m | - | - | - | - | - | - |
| Delaware | | | | | | | | |
| DC | | | | | | | | |
| Florida | | | | | | | | |
| Georgia | Entire project | We test in miles but can break it down using ICC program. | Depends on what type surface is being tested. | - | - | - | - | - |
| Hawaii | | | | | | | | |
| Idaho | | | | | | | | |
| Illinois | Acceptance testing is performed on 100% of the project.<br>Entire project | 0.1 mile | 0.20 inch blanking band<br>Correction Limit =15 in/mi<br><br>0.00 inch blanking band<br>Correction Limit =30 in/mi | - | - | - | - | - |
| Indiana | | | | | | | | |
| Iowa | Entire project | 0.1 mile | Schedule A<br>7.1 to 10 in/mi<br><br>Schedule B<br>22.1 to 30.0 in/mi | - | - | - | - | - |
| Kansas | Entire project | 0.1 mile<br>0.1 km | See Special Provision Chart | - | - | - | - | - |
| Kentucky | Entire project | 1 mile | - | - | - | - | - | - |

| | Q5b | Q5c | Q5d | Q6 | Q6a | Q6b | Q6c | Q6d |
|---|---|---|---|---|---|---|---|---|
| Agency | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | For AC overlay AC what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? |
| Louisiana | Entire project | 0.05 mile increments | See attached Table 502<br>(>75 for Category A, >89 for Category B, >110 for Category C) | - | - | - | - | - |
| Maine | | | | | | | | |
| Maryland | Contractor performs 100% Quality Control testing; Agency performs 100% Quality Assurance on nearly all projects | 25 feet | IRI >= 120-200 in/mi in a 25 ft long section, varies by functional class | - | - | - | - | - |
| Massachusetts | | | | | | | | |
| Michigan | Average of both wheelpaths in each lane. | 0.1 mile | Above 40 RQI<br>PI > 29 in/mi | - | - | - | - | - |
| Minnesota | Entire project with exclusion areas | On projects values every 528 feet<br><br>For yearly certification 500 feet | For certification, must be within +/- 10% of Australian walking profiler.<br><br>For projects, see attached sheets. | - | - | - | - | - |

| | Q5b | Q5c | Q5d | Q6 | Q6a | Q6b | Q6c | Q6d |
|---|---|---|---|---|---|---|---|---|
| Agency | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | For AC overlay AC what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? |
| Mississippi | Entire project | 0.1 mile | - | Profile Index (PI) | in/mi<br>m/km | Entire project | 0.1 mile | - |
| Missouri | Entire project | 0.1 mile | Must grind bumps. | - | - | - | - | - |
| Nebraska | | | | | | | | |
| Nevada | Entire project | 0.1 mile | ? | - | - | - | - | - |
| New Hampshire | | | | | | | | |
| New Jersey | | | | | | | | |
| New Mexico | | | | | | | | |
| New York | Entire project | 200 m lots | 1.50 m/km | - | - | - | - | - |

| Agency | Q5b<br>What is your data sampling method for ride quality data? | Q5c<br>What is the test segment length? | Q5d<br>What is your correction limit? | Q6<br>For AC overlay AC what kind of index is being used? | Q6a<br>What units are used? | Q6b<br>What is your data sampling method for ride quality data? | Q6c<br>What is the test segment length? | Q6d<br>What is your correction limit? |
|---|---|---|---|---|---|---|---|---|
| North Carolina | | | | | | | | |
| North Dakota | - | - | - | Not applicable | - | - | - | - |
| Ohio | | | | | | | | |
| Oklahoma | | | | | | | | |
| Oregon | Entire project | 200 m | 400 mm/km | Profile Index (PI) | m/km | Entire project | 200 m | 400 mm/km |
| Pennsylvania | Entire project | 528' | No limit | - | - | - | - | - |
| Puerto Rico | Entire project | 0.3 mi | PI<=15 (credit to avoid penalties $200/PI)<br>PI=15-40 penalties $200/PI<br>PI>40 Removal and replace | - | - | - | - | - |
| Rhode Island | | | | | | | | |
| South Carolina | | | | | | | | |
| South Dakota | - | - | - | - | - | - | - | - |
| Tennessee | Entire project | Asphalt pavements 1.0 mile lots<br>PCC pavement 0.1 mil sub lots | Varies with pavement type<br>PCC 9 in/mi with 0.1 in blanking band<br>AC (interstate) 70 in/mi | - | - | - | - | - |

| | Q5b | Q5c | Q5d | Q6 | Q6a | Q6b | Q6c | Q6d |
|---|---|---|---|---|---|---|---|---|
| Agency | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | For AC overlay AC what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? |
| Texas | Entire project | 0.1 mile | - | International Roughness Index (IRI) | in/mi | The entire project except leave out sections bridges, approach slabs (100 ft from each side of bridge). | 0.1 mile | - |
| Utah | Entire project | 0.1 mile | Not to exceed 20 sq yd.<br><br>Any section requiring grinding exceeding 20 sq yd does not qualify for incentive. | - | - | - | - | - |
| Vermont | Entire project | 0.1 mile | N/A | International Roughness Index (IRI) | in/mi<br>m/km | Entire project | 0.1 mile | N/A |
| Virginia | Entire project | 0.01 mile (52.8 ft) | 100 Interstate<br>110 Non-Interstate | - | - | - | - | - |
| Washington | Entire project | 0.1 mile | - | - | - | - | - | - |
| West Virginia | Entire project | 0.1 mile<br>0.16 km | Value 50% > specification values. | - | - | - | - | - |
| Wisconsin | | | | | | | | |
| Wyoming | Entire length of completed job | 0.1 mile | - | - | - | - | - | - |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| Alabama | - | - | - | - | - | Contractor<br>Agency reduces the trace. | Within 24 hours | Both wheel paths<br>Right wheel path of right lane. Left wheel path of left lane. Engineer chooses other lanes. | Both |
| Alaska | - | - | - | - | - | Agency | Within 7 days<br><br>Other: Before final acceptance | Left wheel path<br><br>Both wheel paths | Travel lanes<br><br>All traveled lanes |
| Arizona | | | | | | | | | |
| Arkansas | | | | | | | | | |
| California | Profile Index (PI) | m/km | Entire project | 0.1 km | 48 mm / 0.1 km | Contractor<br>Other: In the presence of the engineer. | No time requirement / As soon as possible | Both wheel paths | All<br>Any lane greater than 500 m |
| Colorado | Profile Index (PI) | - | - | - | - | Contractor | No time requirement / As soon as possible | Both wheel paths | All |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| Connecticut | - | - | - | - | - | Agency | Within 30 days | Both wheel paths | All |
| Delaware | | | | | | | | | |
| DC | | | | | | | | | |
| Florida | | | | | | | | | |
| Georgia | - | - | - | - | - | Agency | No time requirement / As soon as possible | Both wheel paths | All lanes resurfaced or new pavement are tested. |
| Hawaii | | | | | | | | | |
| Idaho | | | | | | | | | |
| Illinois | - | - | - | - | - | Contractor<br>Conducts testing on the 0.0 inch blanking band projects.<br><br>Agency<br>Conducts testing on projects using the 0.20 blanking bad projects. | Within 24 hours<br>Unless approved by the Engineer | Both wheel paths<br>Both wheel paths are collected on full-depth bituminous pavements; the wheel path away from traffic is collected on bituminous overlays using the 0.00 inch blanking band. | All |
| Indiana | | | | | | | | | |
| Iowa | - | - | - | - | - | Contractor<br>Agency | Within 24 hours<br>Within 48 hours | Center of lane | Both |
| Kansas | - | - | - | - | - | Contractor | AC<br>Within 24 hours<br><br>PCC<br>Within 48 hours | Both wheel paths | Both |
| Kentucky | - | - | - | - | - | Agency | No time requirement / As soon as possible<br>Testing is scheduled soon as informed. | Both wheel paths | All |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| Louisiana | - | - | - | - | - | Contractor<br>Subject to agency's verification and approval | The contractor shall test the pavement during the first work day following placement but in no case any later than 7 days. | Both wheel paths | - |
| Maine | | | | | | | | | |
| Maryland | - | - | - | - | - | Contactor<br>Other: Contractor collects data with Agency QA checks | Within 72 hours | Both wheel paths | - |
| Massachusetts | | | | | | | | | |
| Michigan | - | - | - | - | - | Contractor<br>Agency on preventive maintenance jobs only. | No time requirement / As soon as possible | Both wheel paths | - |
| Minnesota | - | - | - | - | - | Contractor | Within 48 hours | Other: 9 feet from centerline | Both |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| Mississippi | Profile Index (PI) | in/mi<br>m/km | Entire project | 0.1 mile | - | Contractor | No time requirement / As soon as possible | Right wheel path | Both |
| Missouri | - | - | - | - | - | Contractor<br>Other: Contractor does QC testing. MODOT tests 10% for QA. | Within 24 hours | Other: Either wheel path, one pass per lane. | -<br>All lanes |
| Nebraska | | | | | | | | | |
| Nevada | - | - | - | - | - | Contractor collects<br>Agency reviews & accepts the data | Within 24 hours<br><br>Other: Specifications state 24 hours. Sometimes this is hard to achieve. | Right wheel path | All travel lanes |
| New Hampshire | | | | | | | | | |
| New Jersey | | | | | | | | | |
| New Mexico | | | | | | | | | |
| New York | - | - | - | - | - | Contractor | Other:  Before acceptance | Right wheel path | Both |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| North Carolina | | | | | | | | | |
| North Dakota | Not applicable | - | - | - | - | Agency | No time requirement / As soon as possible | Other: N/A | - |
| Ohio | | | | | | | | | |
| Oklahoma | | | | | | | | | |
| Oregon | Profile Index (PI) | m/km | Entire project | 200 m | 400 mm/km | Contractor | Other: Within 7 calendar days. | Right wheel path | Both |
| Pennsylvania | - | - | - | - | - | Contractor | No time requirement / As soon as possible | Both wheel paths | Both |
| Puerto Rico | - | - | - | - | - | Agency | No time requirement / As soon as possible | Right wheel path | - |
| Rhode Island | | | | | | | | | |
| South Carolina | | | | | | | | | |
| South Dakota | - | - | - | - | - | Contractor | Within 24 hours | - | - |
| Tennessee | - | - | - | - | - | | | | |

| | Q7 | Q7a | Q7b | Q7c | Q7d | Q8 | Q9 | Q10 | Q10a |
|---|---|---|---|---|---|---|---|---|---|
| Agency | For AC overlay PCC, what kind of index is being used? | What units are used? | What is your data sampling method for ride quality data? | What is the test segment length? | What is your correction limit? | Who is responsible for smoothness acceptance testing? | How soon is acceptance testing performed after construction? | For AC pavements, where is the longitudinal profile measurement taken? | Which lane is testing performed in? |
| Texas | International Roughness Index (IRI) | in/mi | Entire project | 0.1 mile | - | Contractor<br>Other: TX DOT can verify the results if questionable. | Within 24 hours<br>Other: Within 24 hours after getting approval from engineer. | Both wheel paths | All travel lanes |
| Utah | - | - | - | - | - | Contractor | No time requirement / As soon as possible | Both wheel paths | Both<br>Including shoulders exceeding 8ft width. |
| Vermont | International Roughness Index (IRI) | in/mi<br>m/km | Entire project | 0.1 mile | N/A | Agency | No time requirement / As soon as possible<br>Other: 1 week | Both wheel paths | Both |
| Virginia | - | - | - | - | - | Agency | Other: Within 30 days | Both wheel paths | Both |
| Washington | - | - | - | - | - | Agency | Other: Current spec is 20 days, but envision probably 10 days with new specification. | Both wheel paths | All |
| West Virginia | - | - | - | - | - | Agency | Other: Within 30 days | Both wheel paths | All new lanes. |
| Wisconsin | | | | | | | | | |
| Wyoming | - | - | - | - | - | Contractor | Within 48 hours | Both wheel paths | All pavement laid tested for profile analysis excluding shoulders. |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| Alabama | Direction of travel | One |
| Alaska | Direction of travel | One<br><br>1 per lane |
| Arizona | | |
| Arkansas | | |
| California | No requirement | One initial<br>As many as necessary after corrections. |
| Colorado | Direction of travel | 0 |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| Connecticut | Direction of travel | One run per lane. |
| Delaware | | |
| DC | | |
| Florida | | |
| Georgia | Bidirectional | It depends on whether the project passes (one run), or fails. We will run again on failing numbers just to make sure it's correct. |
| Hawaii | | |
| Idaho | | |
| Illinois | Direction of travel | 1<br>One run is required for initial testing. If any corrective action is performed, a second run is collected to insure that the PI is brought to the acceptable level. |
| Indiana | | |
| Iowa | Direction of travel | 1 |
| Kansas | Other: Traffic direction for inventory.<br><br>Direction of paver travel for construction. | two tracks per lane. |
| Kentucky | Bidirectional | 2 (minimum) |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| Louisiana | Direction of travel | The contractor shall measure the top two lifts of the roadway travel lanes. Final acceptance will be based on the last measurement taken on the final wearing course of the travel lanes (the top or last lift placed). |
| Maine | | |
| Maryland | Direction of travel | Three runs with a coefficient of variation less than or equal to 4%. |
| Massachusetts | | |
| Michigan | No requirement<br>2006 Spec will require in direction of travel (to ease verification). | 1 |
| Minnesota | Direction of travel | 1 |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| Mississippi | No requirement | Agency typically none. Contractor one run. Agency collects if directed by the engineer. |
| Missouri | Direction of travel | Random 10% for QA. |
| Nebraska | | |
| Nevada | Direction of travel | As many as it takes for every foot of every travel lane. |
| New Hampshire | | |
| New Jersey | | |
| New Mexico | | |
| New York | Direction of travel | Average of three runs per lot. |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| North Carolina | | |
| North Dakota | Direction of travel | One per lane |
| Ohio | | |
| Oklahoma | | |
| Oregon | No requirement | 1 |
| Pennsylvania | Direction of travel | 1 |
| Puerto Rico | Direction of travel | 1 |
| Rhode Island | | |
| South Carolina | | |
| South Dakota | Direction of travel | As needed. |
| Tennessee | | |

| | Q11 | Q12 |
|---|---|---|
| Agency | What direction is testing performed? | How many runs does your agency collect per project? |
| Texas | Direction of travel | - |
| Utah | No requirement | One on each wheel path and shoulder, >8' and average. |
| Vermont | Direction of travel | 1 |
| Virginia | Bidirectional | 2 runs (lowest 0.01 mile IRI used per pay lot). |
| Washington | Direction of travel | - |
| West Virginia | Direction of travel | Three passes per lane. |
| Wisconsin | | |
| Wyoming | Direction of travel | 3 runs in each lane for smoothness testing. |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| Alabama | Yes | Yes | AC Pavements<br>PI < 10 in/mi PF = 105-(PI / 2.0)<br>10 in/mi < PI <20 in/mi PF = 100<br>20 in/mi < PI <50 in/mi PF = 100- (PI-20.0) / 1.5 | PI < 10 in/mi PF = 105-(PI / 2.0) |
| Alaska | Yes | ride > 8"/mile results in penalty<br><br>15" / mile | Separate pay factor for ride<br><br>Pay factor = 0.0583-0.0083 PRI in/mi using 0.2"/mile blank (multiply by 100 for %) | PI < 6" results in a bonus, >.8 results in a penalty<br><br>No upper limit, 7"/mile = 0 pay factor |
| Arizona | | | | |
| Arkansas | | | | |
| California | No<br>Soon to be used. | Correct when exceeds 90 mm / 0.1 km | Will pay 5%. | Pay up to 29.9 mm / 0.1 km |
| Colorado | Yes | PI=24.1 in/mi for interstate<br><br>PI=28.1 in/mi for non-interstate with speed limit over 45 mph<br><br>PI=34.1 in/mi for all others | AC pavements<br>Interstate<br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-10.0 in/mi results in $0.075/sq yd<br>PI=10.1-12.0 in/mi results in $0.05/sq yd<br>PI=12.1-14.0 in/mi results in $0.025/sq yd<br>PI=14.1-16.0 in/mi results in $0.00/sq yd<br>PI=16.1-18.0 in/mi results in -$0.025/sq yd<br>PI=18.1-20.0 in/mi results in -$0.05/sq yd<br>PI=20.1-22.0 in/mi results in -$0.075/sq yd<br>PI=22.1-24.0 in/mi results in -$0.10/sq yd<br>Correction required if PI>24.1 in/mi<br><br>Non-Interstate Speed Greater Than 45 mph<br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-10.6 in/mi results in $0.075/sq yd<br>PI=10.7-13.3 in/mi results in $0.05/sq yd<br>PI=13.4-16.0 in/mi results in $0.025/sq yd<br>PI=16.1-18.0 in/mi results in $0.00/sq yd<br>PI=18.1-20.5 in/mi results in -$0.025/sq yd<br>PI=20.6-23.0 in/mi results in -$0.05/sq yd<br>PI=23.1-25.5 in/mi results in -$0.075/sq yd<br>PI=25.6-28.0 in/mi results in -$0.10/sq yd<br>Correction required if PI>28.1 in/mi<br><br>All Others<br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-11.7 in/mi results in $0.075/sq yd | Interstate<br>PI=8-14 in/mi<br><br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-10.0 in/mi results in $0.075/sq yd<br>PI=10.1-12.0 in/mi results in $0.05/sq yd<br>PI=12.1-14.0 in/mi results in $0.025/sq yd<br>PI=14.1-16.0 in/mi results in $0.00/sq yd<br><br>Non-interstate with speed limit over 45 mph<br>PI=8-16 in/mi<br><br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-10.6 in/mi results in $0.075/sq yd<br>PI=10.7-13.3 in/mi results in $0.05/sq yd<br>PI=13.4-16.0 in/mi results in $0.025/sq yd<br>PI=16.1-18.0 in/mi results in $0.00/sq yd<br><br>All others<br>PI=8-18 in/mi<br><br>PI < 8.0 in/mi results in $0.10/sq yd<br>PI=8.1-11.7 in/mi results in $0.075/sq yd<br>PI=11.8-15.4 in/mi results in $0.05/sq yd<br>PI=15.5-18.0 in/mi results in $0.025/sq yd<br>PI=18.1-20.0 in/mi results in $0.00/sq yd |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| Connecticut | Yes<br>Only used on selected projects. | No maximum for IRI.<br>However, only 50% payment given when IRI exceeds 1.893 m/km. | See special provision. (DRAFT)<br><br>Bituminous Concrete Adjustment Schedule<br>IRI <0.789 m/km results in PF=1.10<br>IRI=0.789-0.947 m/km results in PF=1+0.6329 (0.947-IRI)<br>IRI=0.948-1.262 m/km results in PF=1.0<br>IRI=1.263-1.893 m/km results in PF=1+0.3968 (1.263-IRI)<br>IRI>1.893 m/km results in PF=0.5 | 0.789 m/km =1.10<br>1.893 m/km =0.50<br><br>Bituminous Concrete Adjustment Schedule<br>IRI <0.789 m/km results in PF=1.10<br>IRI=0.789-0.947 m/km results in PF=1+0.6329 (0.947-IRI) |
| Delaware | | | | |
| DC | | | | |
| Florida | | | | |
| Georgia | No | No | N/A | N/A |
| Hawaii | | | | |
| Idaho | | | | |
| Illinois | Yes | 0.20 inch blanking band<br>PI>15 in/mi<br><br>0.00 inch blanking band<br>PI >30 in/mi | -<br>The specification and special provision have ranges of smoothness that allow different incentives and disincentives. | The PI values and payouts differ between the types of pavements. |
| Indiana | | | | |
| Iowa | Yes | Yes<br>Schedule A<br>PI greater than 10.1 in/mi needs to be corrected.<br><br>Schedule B<br>PI greater than 30.1 in/mi needs to be corrected. | - | Schedule A<br>Incentive Upper Limit is PI = 3.0 in/mi<br>Incentive Lower Limit is PI = 0 in/mi<br><br>Schedule B<br>Incentive Upper Limit is PI = 12.0 in/mi<br>Incentive Lower Limit is PI = 0 in/mi |
| Kansas | Yes | PI=30 in/mi | See charts.<br><br>AC<br>PI<7.0 in/mi results in $152.00/section/lane<br>PI=7.1-10.0 in/mi results in $76.00/section/lane<br>PI=10.1-30.0 in/mi results in $0.00/section/lane<br>PI=30.1-40.0 in/mi results in $0.00/section/lane**<br>PI>40.1 in/mi results in -$203.00/section/lane<br>**Correct to 30.0 in/mi | AC<br>PI=0-10 in/mi<br><br>PI<7.0 in/mi results in $152.00/section/lane<br>PI=7.1-10.0 in/mi results in $76.00/section/lane<br><br>PCC<br>PI=0-18 in/mi |
| Kentucky | Yes | Yes<br>76 in/mi for greater than 45 mph.<br>86 in/mi for less than or equal to 45 mph.<br>Corrective action required for IRI greater than these values. | Incentive -- 0.015 x (47-IRI)<br>Disincentive -- 0.015 x (67-IRI) | +/- 15% AC |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| Louisiana | Yes | See Table 502.<br><br>Category A (multi-lift new, OL > 2 lifts, all interstates)<br>IRI>75 in/mi results in PF =50% or Remove<br><br>Category B (OL 2-1 lift over cold planed, 2 lift over existing)<br>IRI>89 in/mi results in PF =50% or Remove<br><br>Category C (1 lift over existing)<br>IRI>110 in/mi results in PF =50% or Remove | See Table 502.<br><br>Category A (multi-lift new, OL > 2 lifts, all interstates)<br>IRI<55 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=56-64 in/mi results in PF=100% of Contract Unit Price by Sublot<br>IRI=65-75 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI>75 in/mi results in PF =50% or Remove<br><br>Category B (OL 2-1 lift over cold planed, 2 lift over existing)<br>IRI<65 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=66-74 in/mi results in PF=100% of Contract Unit Price by Sublot<br>IRI=75-89 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI>89 in/mi results in PF =50% or Remove<br><br>Category C (1 lift over existing)<br>IRI<75 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=76-84 in/mi results in PF=100% of Contract Unit Price by Sublot<br>IRI=85-95 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI=96-110 in/mi results in PF=80% of Contract Unit Price by Sublot<br>IRI>110 in/mi results in PF =50% or Remove | See Table 502.<br><br>Category A (multi-lift new, OL > 2 lifts, all interstates)<br>IRI<55 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=56-64 in/mi results in PF=100% of Contract Unit Price by Sublot<br><br>Category B (OL 2-1 lift over cold planed, 2 lift over existing)<br>IRI<65 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=66-74 in/mi results in PF=100% of Contract Unit Price by Sublot<br><br>Category C (1 lift over existing)<br>IRI<75 in/mi results in PF=103% of Contract Unit Price by Sublot<br>IRI=76-84 in/mi results in PF=100% of Contract Unit Price by Sublot |
| Maine | | | | |
| Maryland | Yes | Only within the defect (bump) sections noted above. | The pay factor is related to overall project average IRI. | Maximum incentive is achieved at IRI = 40in/mi or better, incentive decreases linearly to IRI =60 in/mi, where no incentive is earned. |
| Massachusetts | | | | |
| Michigan | No<br>Used to. Eliminated do to budget concerns. | - | - | - |
| Minnesota | Yes | Yes<br>Specified in all three tables.<br><br>3 Lift Minimum Construction<br>Correction Required for PI>7.5 in/mi<br><br>2 Lift Construction<br>Correction Required for PI>10.0 in/mi<br><br>1 Lift Construction<br>Correction Required for PI>16.0 in/mi | 3 Lift Minimum Construction<br>PI = 0.0-0.8 in/mi results in $335/0.1 mi<br>PI = 0.9-1.6 in/mi results in $225/0.1 mi<br>PI = 1.7-2.4 in/mi results in $115/0.1 mi<br>PI = 2.5-5.0 in/mi results in $0/0.1 mi<br>PI = 5.1-5.8 in/mi results in $-115/0.1 mi<br>PI = 5.9-6.7 in/mi results in $-225/0.1 mi<br>PI = 6.8-7.5 in/mi results in $-335/0.1 mi<br><br>2 Lift Construction<br>PI = 0.0-1.0 in/mi results in $225/0.1 mi<br>PI = 1.1-2.0 in/mi results in $150/0.1 mi<br>PI = 2.1-3.0 in/mi results in $75/0.1 mi<br>PI = 3.1-7.0 in/mi results in $0/0.1 mi<br>PI = 7.1-8.0 in/mi results in $-75/0.1 mi<br>PI = 8.1-9.0 in/mi results in $-150/0.1 mi<br>PI = 9.1-10.0 in/mi results in $-225/0.1 mi<br><br>1 Lift Construction<br>PI = 0.0-2.0 in/mi results in $150/0.1 mi<br>PI = 2.1-3.0 in/mi results in $100/0.1 mi<br>PI = 3.1-5.0 in/mi results in $50/0.1 mi<br>PI = 5.1-10.0 in/mi results in $0/0.1 mi<br>PI = 10.1-12.0 in/mi results in $-50/0.1 mi<br>PI = 12.1-14.0 in/mi results in $-100/0.1 mi<br>PI = 14.1-16.0 in/mi results in $-150/0.1 mi | 3 Lift Minimum Construction<br>PI = 0.0-0.8 in/mi results in $335/0.1 mi<br>PI = 0.9-1.6 in/mi results in $225/0.1 mi<br>PI = 1.7-2.4 in/mi results in $115/0.1 mi<br><br>2 Lift Construction<br>PI = 0.0-1.0 in/mi results in $225/0.1 mi<br>PI = 1.1-2.0 in/mi results in $150/0.1 mi<br>PI = 2.1-3.0 in/mi results in $75/0.1 mi<br><br>1 Lift Construction<br>PI = 0.0-2.0 in/mi results in $150/0.1 mi<br>PI = 2.1-3.0 in/mi results in $100/0.1 mi<br>PI = 3.1-5.0 in/mi results in $50/0.1 mi |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| Mississippi | Yes | Yes | HMA Incentive Amounts<br>22-30 in/mi =100%<br>18-22 in/mi =102%<br>14-18 in/mi =104%<br>10-14 in/mi =106%<br><10 in/mi = 108%<br>Correction > 30 in/mi | - |
| Missouri | Yes | Work suspended if greater than 45 in/mi.<br><br>Final Posted Speed Greater Than 45 mph<br>Correction Required for PI> 25.1 in/mi<br><br>Final Posted Speed Less Than or Equal to 45 mph<br>Correction Required for PI > 45.1 in/mi | Smoothness stands alone as a pay factor.<br><br>Final Posted Speed Greater Than 45 mph<br>PI < 10.0 in/mi results in PF = 105<br>PI=10.1-15.0 in/mi results in PF = 103<br>PI=15.1-25.0 in/mi results in PF = 100<br><br>Final Posted Speed Less Than or Equal to 45 mph<br>PI < 20.0 in/mi results in PF = 103<br>PI=20.1-45.0 in/mi results in PF = 100 | Chart in attached specification.<br><br>Final Posted Speed Greater Than 45 mph<br>PI < 10.0 in/mi results in PF = 105<br>PI=10.1-15.0 in/mi results in PF = 103<br><br>Final Posted Speed Less Than or Equal to 45 mph<br>PI < 20.0 in/mi results in PF = 103 |
| Nebraska | | | | |
| Nevada | Yes | 10"/mile<br><br>Corrective work required where PI>10 in/mi | Pay factor of 1.07 equates to 0-1.9 in/mi all the way down to 0.90 for 10 in/mi<br><br>Ride Pay Factor<br>PF = 1.07 PI=0-1.9 in/mi<br>PF = 1.06 PI=2.0-2.5 in/mi<br>PF = 1.05 PI=2.6-3.2 in/mi<br>PF = 1.04 PI=3.3-3.9 in/mi<br>PF = 1.02 PI=4.0-4.5 in/mi<br>PF = 1.00 PI=4.6-5.0 in/mi<br>PF = 0.98 PI=5.1-6.0 in/mi<br>PF = 0.96 PI=6.1-7.0 in/mi<br>PF = 0.94 PI=7.1-8.0 in/mi<br>PF = 0.92 PI=8.1-9.0 in/mi<br>PF = 0.90 PI=9.1-10 in/mi | $1680 / in mile max incentive or -$2400 / in mile owed (disincentive)<br><br>Ride Pay Factor<br>PF = 1.07 PI=0-1.9 in/mi<br>PF = 1.06 PI=2.0-2.5 in/mi<br>PF = 1.05 PI=2.6-3.2 in/mi<br>PF = 1.04 PI=3.3-3.9 in/mi<br>PF = 1.02 PI=4.0-4.5 in/mi |
| New Hampshire | | | | |
| New Jersey | | | | |
| New Mexico | | | | |
| New York | Yes | Yes-correction limit 1.5 m/km | Level 1<br>IRI < 0.60 m/km results in 10 Quality Units<br>IRI = 0.61-0.85 m/km results in 5 Quality Units<br>IRI = 0.86-1.10 m/km results in 0 Quality Units<br>IRI = 1.11-1.30 m/km results in -2.5 Quality Units<br>IRI = 1.31-1.50 m/km results in -5 Quality Units<br>IRI > 1.50 m/km results in -10 Quality Units<br><br>Level 2-2+ Courses<br>IRI < 0.75 m/km results in 10 Quality Units<br>IRI = 0.75-1.00 m/km results in 5 Quality Units<br>IRI = 1.01-1.25 m/km results in 0 Quality Units<br>IRI = 1.26-1.45 m/km results in -2.5 Quality Units<br>IRI = 1.46-1.65 m/km results in -5 Quality Units<br>IRI > 1.65 m/km results in -10 Quality Units<br><br>Level 2-1 Course<br>IRI < 0.75 m/km results in 5 Quality Units<br>IRI = 0.75-1.00 m/km results in 2.5 Quality Units<br>IRI = 1.01-1.25 m/km results in 0 Quality Units<br>IRI = 1.26-1.45 m/km results in -1.25 Quality Units<br>IRI = 1.46-1.65 m/km results in -2.5 Quality Units<br>IRI > 1.65 m/km results in -5 Quality Units | Level 1<br>IRI < 0.60 m/km results in 10 Quality Units<br>IRI = 0.61-0.85 m/km results in 5 Quality Units<br><br>Level 2-2+ Courses<br>IRI < 0.75 m/km results in 10 Quality Units<br>IRI = 0.75-1.00 m/km results in 5 Quality Units<br><br>Level 2-1 Course<br>IRI < 0.75 m/km results in 5 Quality Units<br>IRI = 0.75-1.00 m/km results in 2.5 Quality Units |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| North Carolina | | | | |
| North Dakota | Yes<br>PCC pavement only. | Yes | dollar amount based on profile index, inches per 0.1 mile. | 0.0-2.0 inches per 0.1 mile |
| Ohio | | | | |
| Oklahoma | | | | |
| Oregon | Yes | Yes<br>400 mm/km<br><br>PI = 45 mm/km or less results in a Contract unit price adjustment of +3.0%<br>PI = 46-75 mm/km results in a Contract unit price adjustment of +0.0968 x (76-PI)%<br>PI = 76-110 mm/km results in a Contract unit price adjustment of NONE<br>PI = 111-140 mm/km results in a Contract unit price adjustment of 0.0968 x (110-PI)%<br>PI = 141-175 mm/km results in a Contract unit price adjustment of -3.0%<br>PI = 176 mm/km or greater results in REMOVE AND REPLACE | See attached.<br><br>PI = 45 mm/km or less results in a Contract unit price adjustment of +3.0%<br>PI = 46-75 mm/km results in a Contract unit price adjustment of +0.0968 x (76-PI)%<br>PI = 76-110 mm/km results in a Contract unit price adjustment of NONE<br>PI = 111-140 mm/km results in a Contract unit price adjustment of 0.0968 x (110-PI)%<br>PI = 141-175 mm/km results in a Contract unit price adjustment of -3.0%<br>PI = 176 mm/km or greater results in REMOVE AND REPLACE | See attached.<br><br>PI = 45 mm/km or less results in a Contract unit price adjustment of +3.0%<br>PI = 46-75 mm/km results in a Contract unit price adjustment of +0.0968 x (76-PI)% |
| Pennsylvania | Yes | Yes<br>70 IRI<br><br>Expressway using 3 operations<br>IRI >70 in/mi needs to be corrected<br><br>Expressway using 2 operations / non-expressway<br>IRI >90 in/mi needs to be corrected | Bracketed lump sum<br><br>Expressway using 3 operations<br>IRI=<35 in/mi/lot results in PF=$600<br>IRI=36-50 in/mi/lot results in PF=$300<br>IRI=51-60 in/mi/lot results in PF=$150<br>IRI=61-70 in/mi/lot results in PF=$0<br>IRI >70 in/mi needs to be corrected<br><br>Expressway using 2 operations / non-expressway<br>IRI=<45 in/mi/lot results in PF=$600<br>IRI=46-55 in/mi/lot results in PF=$300<br>IRI=56-70 in/mi/lot results in PF=$150<br>IRI=71-90 in/mi/lot results in PF=$0<br>IRI >70 in/mi needs to be corrected | 60-35 IRI<br><br>Expressway using 3 operations<br>IRI=<35 in/mi/lot results in PF=$600<br>IRI=36-50 in/mi/lot results in PF=$300<br>IRI=51-60 in/mi/lot results in PF=$150<br><br>Expressway using 2 operations / non-expressway<br>IRI=<45 in/mi/lot results in PF=$600<br>IRI=46-55 in/mi/lot results in PF=$300<br>IRI=56-70 in/mi/lot results in PF=$150 |
| Puerto Rico | Not applicable<br>As specified, there is a credit of $200/PI for PI<15, to reduce the amount of penalties. | - | - | - |
| Rhode Island | | | | |
| South Carolina | | | | |
| South Dakota | Yes | Yes<br>PI<=40.1 in/mi results in correction. | - | 10.0, 25.0 |
| Tennessee | | | | |

| | INCENTIVE / DISINCENTIVE | | | |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| Agency | Does your agency have an incentive / disincentive program? | Is there a maximum acceptable roughness? | How is your pay factor equation related to smoothness? | What is the lower limit and upper limit of your incentive program? |
| Texas | Yes | IRI of 95 in/mi for pay schedule 1 and 2. | -<br>Schedule 1<br>IRI<30 in/mi results in PF = $600/0.1 mi<br>IRI=31-59 in/mi results in PF = $600-20(IRI-30)<br>IRI=60-65 in/mi results in PF = $0/0.1 mi<br>IRI=66-95 in/mi results in PF=-$20(IRI-65)<br>IRI>95 needs correction action<br><br>Schedule 2<br>IRI<30 in/mi results in PF = $600/0.1 mi<br>IRI=31-59 in/mi results in PF = $600-20(IRI-30)<br>IRI=60-75 in/mi results in PF = $0/0.1 mi<br>IRI=76-95 in/mi results in PF=-$20(IRI-75)<br>IRI>95 needs correction action | $20 per 0.1 mile<br>$600 per 0.1 mile<br>(depends on pay schedule)<br><br>Schedule 1<br>IRI<30 in/mi results in PF = $600/0.1 mi<br>IRI=31-59 in/mi results in PF = $600-20(IRI-30)<br><br>Schedule 2<br>IRI<30 in/mi results in PF = $600/0.1 mi<br>IRI=31-59 in/mi results in PF = $600-20(IRI-30) |
| Utah | Yes | Attached formula sheet 7"/mile.<br><br>NHS & Truck routes and 3 or more opportunities should have PI<5 in/mi<br>All other routes and not more than two opportunities should have PI<7 in/mi | Attached a formula sheet.<br><br>NHS & Truck routes and 3 or more opportunities<br>Incentive/Disincentive per section = $60 x [(Required in/mi)-(PI)]<br><br>All other routes and not more than two opportunities should have PI<7 in/mi<br>Incentive/Disincentive per section = $30 x [(Required in/mi)-(PI)] | According to attached formula sheet, no lower limit. |
| Vermont | Yes | No | Limited Access<br>PF=1.1278-(0.0022*IRI) with IRI-in/mi<br><br>All Other<br>PF=1.1389-(0.0022*IRI) with IRI-in/mi | Function of IRI |
| Virginia | Yes | Yes, see Q5 (Gold Q5). | Pay Steps | <55 Interstate<br><65 Non-Interstate |
| Washington | Yes<br>To be developed with new spec. Will closely follow AASHTO provisional standard. | - | - | - |
| West Virginia | Yes<br>Price reduction up to the 50% over spec limit. | 50% over spec.<br><br>When measured smoothness value exceeds the specified value by 50% or more the LOT so measured shall be corrected at the Contractors expense.<br><br>Total New Pavement Thickness 3 in to less than 4 in -- greater than 121.5 in/mi<br>Total New Pavement Thickness 4 in or greater -- greater than 97.5 in/mi | Unit bid price.<br><br>Total New Pavement Thickness 3 in to less than 4 in -- should be 81 in/mi or less<br>Total New Pavement Thickness 4 in or greater -- should be 65 in/mi or less | N/A<br><br>There does not appear to be an incentive. |
| Wisconsin | | | | |
| Wyoming | Yes | No, but deductions can be assessed as roughness increases. | Smoothness average plus 1/2 average standard deviation is used on chart. | For plant mix values ≤ 55 is bonus. For wearing course values ≤ 45 is bonus. |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| Alabama | 10 in/mi < PI <20 in/mi PF = 100 | 20 in/mi < PI <50 in/mi PF = 100- (PI-20.0) / 1.5 | Research and analysis<br>Other agencies specification<br>Engineering judgment | Portion of unit bid: $ / ton |
| Alaska | ride of PI 6-8" results in full pay<br><br>No upper limit, 7"/mile = 0 pay factor | -<br><br>See Q3. | Other agencies specifications<br>Engineering judgment<br><br>Research and analysis | Fixed amount: 15 k for each inch improvement; with max bonus and penalty of 50 k per project. Other: <10%<br><br>Portion of unit bid: Contract unit price * contract qty* pay factor |
| Arizona | | | | |
| Arkansas | | | | |
| California | 30-45 mm / 0.1 km | 45.1-60 mm / 0.1 km | Research and analysis<br>Other agencies specification<br>Engineering judgment<br><br>Other: Combination of the three. | Fixed amount: $ per 0.1 km |
| Colorado | PI=8 in/mi<br><br>Interstate<br>PI=14.1-16.0 in/mi results in $0.00/sq yd<br><br>Non-Interstate Speed Greater Than 45 mph<br>PI=16.1-18.0 in/mi results in $0.00/sq yd<br><br>All Others<br>PI=18.1-20.0 in/mi results in $0.00/sq yd | Interstate<br>PI=16-24 in/mi<br><br>PI=16.1-18.0 in/mi results in -$0.025/sq yd<br>PI=18.1-20.0 in/mi results in -$0.05/sq yd<br>PI=20.1-22.0 in/mi results in -$0.075/sq yd<br>PI=22.1-24.0 in/mi results in -$0.10/sq yd<br>Correction required if PI>24.1 in/mi<br><br>Non-interstate with speed limit over 45 mph<br>PI=18-28 in/mi<br><br>PI=18.1-20.5 in/mi results in -$0.025/sq yd<br>PI=20.6-23.0 in/mi results in -$0.05/sq yd<br>PI=23.1-25.5 in/mi results in -$0.075/sq yd<br>PI=25.6-28.0 in/mi results in -$0.10/sq yd<br>Correction required if PI>28.1 in/mi<br><br>All others<br>PI=20-34 in/mi<br><br>PI=20.1-23.0 in/mi results in -$0.025/sq yd<br>PI=23.1-26.0 in/mi results in -$0.05/sq yd<br>PI=26.1-29.0 in/mi results in -$0.075/sq yd<br>PI=29.1-34.0 in/mi results in -$0.10/sq yd<br>Correction required if PI>34.1 in/mi | Research and analysis | Fixed amount: $ per square yard |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| Connecticut | See special provision.<br><br>Bituminous Concrete Adjustment Schedule<br>IRI=0.948-1.262 m/km results in PF=1.0 | See special provision.<br><br>Bituminous Concrete Adjustment Schedule<br>IRI=1.263-1.893 m/km results in PF=1+0.3968 (1.263-IRI)<br>IRI>1.893 m/km results in PF=0.5 | Research and analysis<br>Other agencies specification<br>Engineering judgment | See special provision.<br><br>CT DOT calculates a Rideability Adjustment and then multiplies it by the HMA tons and Contract Bid Price. |
| Delaware | | | | |
| DC | | | | |
| Florida | | | | |
| Georgia | N/A | - | Research and analysis | N/A |
| Hawaii | | | | |
| Idaho | | | | |
| Illinois | 0.20 inch blanking band<br>PI=4-10 in/mi for PCC pavements<br>Full Pay of 100 PI=0.5-10 in/mi for full depth bituminous pavements<br><br>0.00 inch blanking band<br>PI =10-30 in/mi for bituminous overlays<br>PI=17-30 in/mi for PCC and full depth bituminous pavements | 0.20 inch blanking band<br>PI>15 in/mi<br><br>0.00 inch blanking band<br>PI >30 in/mi | Research and analysis<br>Other agencies specifications | **Fixed amount:** 0.00 inch blanking band projects<br>**Portion of unit bid:** 0.20 inch blanking band projects |
| Indiana | | | | |
| Iowa | Schedule A<br>Full Pay Upper Limit is PI = 7.0 in/mi<br>Full Pay Lower Limit is PI = 3.1 in/mi<br><br>Schedule B<br>Full Pay Upper Limit is PI = 22.0 in/mi<br>Full Pay Lower Limit is PI = 12.1 in/mi | Schedule A<br>Grind Only for PI > 10.1<br>Disincentive Upper Limit is PI = 10.0 in/mi<br>Disincentive Lower Limit is PI = 7.1 in/mi<br><br>Schedule B<br>Grind Only for PI >22.1<br>Full Pay Upper Limit is PI = 22.0 in/mi<br>Full Pay Lower Limit is PI = 12.1 in/mi | Research and analysis<br>Other agencies specifications<br>Engineering judgment | Fixed amount: $/segment |
| Kansas | AC<br>PI=10-40 in/mi<br><br>PI=10.1-30.0 in/mi results in $0.00/section/lane<br>PI=30.1-40.0 in/mi results in $0.00/section/lane**<br>**Correct to 30.0 in/mi<br><br>PCC<br>PI=18-40 in/mi<br><br>Grind back to 30 in/mi | PI=30-40 results in Full Pay but correct to 30 in/mi<br><br>PI>40 in/mi results in penalty and correct to 30 in/mi | Research and analysis<br>Engineering judgment | Fixed amount: see charts. |
| Kentucky | AC Pavements<br>Pay Value Adjustment For Speed Greater Than 45 mph<br>0.15 for 36 in/mi or lower<br>0.015 x (47-IRI) for 37-46 in/mi<br>0.00 for 47-66 in/mi<br>0.015 x (67-IRI) for 67-76 in/mi<br>Corrective work or replacement required for 77 in/mi or higher<br>Pay Value Adjustment For 45 mph or Lower<br>0.15 for 36 in/mi or lower<br>0.015 x (47-IRI) for 37-46 in/mi<br>0.00 for 47-85 in/mi<br>Corrective work or replacement required for 86 in/mi or higher | - | Research and analysis<br>Engineering judgment | Portion of unit bid |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| Louisiana | See Table 502.<br><br>Category A (multi-lift new, OL > 2 lifts, all interstates)<br>IRI=56-64 in/mi results in PF=100% of Contract Unit Price by Sublot<br><br>Category B (OL 2-1 lift over cold planed, 2 lift over existing)<br>IRI=66-74 in/mi results in PF=100% of Contract Unit Price by Sublot<br><br>Category C (1 lift over existing)<br>IRI=76-84 in/mi results in PF=100% of Contract Unit Price by Sublot | See Table 502.<br><br>Category A (multi-lift new, OL > 2 lifts, all interstates)<br>IRI=65-75 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI>75 in/mi results in PF =50% or Remove<br><br>Category B (OL 2-1 lift over cold planed, 2 lift over existing)<br>IRI=75-89 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI>89 in/mi results in PF =50% or Remove<br><br>Category C (1 lift over existing)<br>IRI=85-95 in/mi results in PF=90% of Contract Unit Price by Sublot<br>IRI=96-110 in/mi results in PF=80% of Contract Unit Price by Sublot<br>IRI>110 in/mi results in PF =50% or Remove | Research and analysis | Portion of unit price: |
| Maine | | | | |
| Maryland | The full pay range begins at IRI=60 and extends to IRI=70-120 (depending on rehab work being done and existing project condition/geometry). | The disincentive range begins at IRI 70-120 and increases linearly to a maximum disincentive at IRI=90-120 (limits depend on rehab work being done and existing project condition/geometry). | Research and analysis<br>Other agencies specifications<br>Engineering judgment | Fixed amount: Maximum amount is 3,500-5,000 dollars per lane mile (varies by functional class). |
| Massachusetts | | | | |
| Michigan | - | - | Research and analysis<br>Other agencies specifications<br>Engineering judgment | - |
| Minnesota | 3 Lift Minimum Construction<br>PI = 2.5-5.0 in/mi results in $0/0.1 mi<br><br>2 Lift Construction<br>PI = 3.1-7.0 in/mi results in $0/0.1 mi<br><br>1 Lift Construction<br>PI = 5.1-10.0 in/mi results in $0/0.1 mi | 3 Lift Minimum Construction<br>PI = 5.1-5.8 in/mi results in $-115/0.1 mi<br>PI = 5.9-6.7 in/mi results in $-225/0.1 mi<br>PI = 6.8-7.5 in/mi results in $-335/0.1 mi<br><br>2 Lift Construction<br>PI = 7.1-8.0 in/mi results in $-75/0.1 mi<br>PI = 8.1-9.0 in/mi results in $-150/0.1 mi<br>PI = 9.1-10.0 in/mi results in $-225/0.1 mi<br><br>1 Lift Construction<br>PI = 10.1-12.0 in/mi results in $-50/0.1 mi<br>PI = 12.1-14.0 in/mi results in $-100/0.1 mi<br>PI = 14.1-16.0 in/mi results in $-150/0.1 mi | Research and analysis<br>Other agencies specifications<br>Engineering judgment | Fixed amount: $/0.1 mi |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| Mississippi | - | No disincentive.<br>Correct anything > 30 in/mi. | Research and analysis | Fixed amount: PCC per sq yd.<br>Portion of unit bid: HMA per surface lift tonnage. |
| Missouri | Final Posted Speed Greater Than 45 mph<br>PI=15.1-25.0 in/mi results in PF = 100<br><br>Final Posted Speed Less Than or Equal to 45 mph<br>PI=20.1-45.0 in/mi results in PF = 100 | Corrective areas considered marred surfaces. A deduction of 20% of the contract price will be made for the affected area. Continuous corrective action performed on the entire pavement width for a length of 0.1 mile will not be considered a marred surface and will receive 100% of the contract price.<br><br>Final Posted Speed Greater Than 45 mph<br>Correction Required for PI> 25.1 in/mi<br><br>Final Posted Speed Less Than or Equal to 45 mph<br>Correction Required for PI > 45.1 in/mi | Research and analysis | Portion of unit bid: see attached spec.<br><br>% of contract price. |
| Nebraska | | | | |
| Nevada | -<br><br>Ride Pay Factor<br><br>PF = 1.00 PI=4.6-5.0 in/mi | -<br><br>Ride Pay Factor<br>PF = 0.98 PI=5.1-6.0 in/mi<br>PF = 0.96 PI=6.1-7.0 in/mi<br>PF = 0.94 PI=7.1-8.0 in/mi<br>PF = 0.92 PI=8.1-9.0 in/mi<br>PF = 0.90 PI=9.1-10 in/mi | - | - |
| New Hampshire | | | | |
| New Jersey | | | | |
| New Mexico | | | | |
| New York | Level 1<br>IRI = 0.86-1.10 m/km results in 0 Quality Units<br><br>Level 2-2+ Courses<br>IRI = 1.01-1.25 m/km results in 0 Quality Units<br><br>Level 2-1 Course<br>IRI = 1.01-1.25 m/km results in 0 Quality Units | Level 1<br>IRI = 1.11-1.30 m/km results in -2.5 Quality Units<br>IRI = 1.31-1.50 m/km results in -5 Quality Units<br>IRI > 1.50 m/km results in -10 Quality Units<br><br>Level 2-2+ Courses<br>IRI = 1.26-1.45 m/km results in -2.5 Quality Units<br>IRI = 1.46-1.65 m/km results in -5 Quality Units<br>IRI > 1.65 m/km results in -10 Quality Units<br><br>Level 2-1 Course<br>IRI = 1.01-1.25 m/km results in 0 Quality Units<br>IRI = 1.26-1.45 m/km results in -1.25 Quality Units<br>IRI = 1.46-1.65 m/km results in -2.5 Quality Units<br>IRI > 1.65 m/km results in -5 Quality Units | Other agencies specifications<br>Engineering judgment<br>AASHTO guide specification | Fixed amount |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| North Carolina | | | | |
| North Dakota | >=2.01-3.00 inches per 0.1 mile | >=3.01 inches per 0.1 mile needs to be corrected | Other agencies specifications<br>Engineering judgment | Fixed amount: Amount based on profile index |
| Ohio | | | | |
| Oklahoma | | | | |
| Oregon | See attached.<br><br>PI = 76-110 mm/km results in a Contract unit price adjustment of NONE | -<br><br>PI = 111-140 mm/km results in a Contract unit price adjustment of 0.0968 x (110-PI)%<br>PI = 141-175 mm/km results in a Contract unit price adjustment of -3.0%<br>PI = 176 mm/km or greater results in REMOVE AND REPLACE | Other agencies specifications | See attached. |
| Pennsylvania | 70-60<br><br>Expressway using 3 operations<br>IRI=61-70 in/mi/lot results in PF=$0<br><br>Expressway using 2 operations / non-expressway<br>IRI=71-90 in/mi/lot results in PF=$0 | Fix every lot less than 70<br><br>Expressway using 3 operations<br>IRI >70 in/mi needs to be corrected<br><br>Expressway using 2 operations / non-expressway<br>IRI >70 in/mi needs to be corrected | Research and analysis<br>Engineering judgment | Fixed amount: |
| Puerto Rico | - | - | - | - |
| Rhode Island | | | | |
| South Carolina | | | | |
| South Dakota | 25.1-35.0 | 35.1-40.0 | Research and analysis<br>Engineering judgment<br>Other agencies specifications<br>AASHTO guide specifications | Fixed amount: |
| Tennessee | | | | |

| Agency | Q5<br>What is the lower limit and upper limit of you full pay provisions? | Q6<br>What is the lower limit and upper limit of you disincentive program? | Q7<br>How were your specified smoothness limits identified? | Q8<br>How are your incentive / disincentive payment amounts determined (calculated)? |
|---|---|---|---|---|
| Texas | -<br>Schedule 1<br>IRI=60-65 in/mi results in PF = $0/0.1 mi<br><br>Schedule 2<br>IRI=60-75 in/mi results in PF = $0/0.1 mi | IRI > 66 for pay schedule 1<br>IRI > 76 for pay schedule 2<br><br>Schedule 1<br>IRI=66-95 in/mi results in PF=-$20(IRI-65)<br>IRI>95 needs correction action<br><br>Schedule 2<br>IRI=76-95 in/mi results in PF=-$20(IRI-75)<br>IRI>95 needs correction action | Research and analysis | Fixed amount: $/0.1 mi |
| Utah | Formula dictates. | Formula dictates. | Research and analysis<br>Engineering judgment | Fixed amount: |
| Vermont | Function of IRI | Function of IRI | Engineering judgment | Portion of unit bid: $/tons |
| Virginia | 55<IRI<70 Interstate<br>65<IRI<80 Non-Interstate | 70-100, Interstate<br>80-110, Non-Interstate | Research and analysis<br>Engineering judgment<br>Other agencies specifications<br>AASHTO guide specifications | Portion of unit bid: |
| Washington | - | - | AASHTO guide specification | - |
| West Virginia | No lower limit, (Spec+1)-Upper Limit.<br><br>For HMA pavement greater than the smoothness values specified, the unit price of the LOT shall be reduced by the following equation.<br><br>*English Units*<br>Reduced unit price = unit bid price * [(127.86-As)/100]<br>Where A = 0.429 when specified smoothness is 65in/mi<br>Where A =0.341 when specified smoothness is 81 in/mi<br>Where s = Smoothness value measured | Spec-lower, 50% above spec then repair-Upper.<br><br>English Units<br>Reduced unit price = unit bid price * [(127.86-As)/100]<br>Where A = 0.429 when specified smoothness is 65in/mi<br>Where A =0.341 when specified smoothness is 81 in/mi<br>Where s = Smoothness value measured<br><br>When measured smoothness value exceeds the specified value by 50% or more the LOT so measured shall be corrected at the Contractors expense.<br><br>Total New Pavement Thickness 3 in to less than 4 in -- greater than 121.5 in/mi<br>Total New Pavement Thickness 4 in or greater -- greater than 97.5 in/mi | Research and analysis | Portion of unit bid: |
| Wisconsin | | | | |
| Wyoming | Plant mix 55-65, Wearing course 45-55. | Plant mix >65, Wearing course >55. | Research and analysis<br>Engineering judgment | Fixed amount: $ per square yard x area paved |

| | QC / QA | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| Alabama | - | - | - | - | - | - |
| Alaska | Daily calibration of equip't., annual comparison with other inertial profilers owned by agency.<br><br>Data evaluation & re-run data if required. | 0-14 mph<br><br>0-70 mph | Manually<br><br>Reflective Stripes | Daily calibration using manufacturer supplied block, bounce test and distance test<br><br>By equip, tilt test of accelerometers | a measured section identified by agency close to DOT offices<br><br>On surveyed section of highway | Training by manufacturer |
| Arizona | | | | | | |
| Arkansas | | | | | | |
| California | Contractor perform tests.<br>Engineer monitor and evaluate. | N/A | N/A | N/A | N/A | N/A |
| Colorado | N/A | Manufacturer specified | Manufacturer specified | Manufacturer specified | - | - |

| | *QC / QA* | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| Connecticut | Run over control sites monthly. | 11-48 mph | Manual. | Control sites monthly. | Calibrated by manufacturer once per year. | Vendor trained. |
| Delaware | | | | | | |
| DC | | | | | | |
| Florida | | | | | | |
| Georgia | - | 15-65 mph | Manually. | Sensor / accelerometer calibration - tire pressure | Manufacturer location | Hands-on training in vehicle. |
| Hawaii | | | | | | |
| Idaho | | | | | | |
| Illinois | When the contractor performs the testing, IDOT performs independent testing on 10% of the project. | Per California Test Method 526 | Manually | N/A | N/A | N/A |
| Indiana | | | | | | |
| Iowa | - | - | - | - | - | - |
| Kansas | - | Profilograph 3 mph<br>Profiler varies with brand.<br>KDOT van 15-70 mph. | Varies with brand.<br>KDOT manually triggers van. | KDOT test track. | Vendor training to operate equip.<br>Classroom training of KDOT specs. | - |
| Kentucky | - | 20-65 mph | Cones and manually. | Check with known sections. | In-house. | In-house training. |

| | QC / QA | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| Louisiana | Defined in attached specifications and also TR 644.<br><br>LADOTD provided their Method of Test for determining the longitudinal profile roughness of traveled surfaces using automated profilers (TR 644-04). | High speed 15-65 mph<br>Lightweight 8-12 mph | Manual<br>Sometimes cone or reflective tapes are also used. | See attached TR 644 under preparation.<br><br>Diagnostics, vertical, horizontal, bounce tests. | Local sites assigned by the department, annual basis. | Vendor's training requirements prior to certification, and competency to perform the certification checks. |
| Maine | | | | | | |
| Maryland | Contractor performs QC testing and agency performs QA testing. | 20-50 mph | Automatically by reflective stripes or cones and manually if traffic conditions are unsafe to tape. | Distance measuring instrument, accelerometers; Routine calibration and runs on verification sites. | At three 'standard' sites around the state. | At present no formal training in place. On site during approval of equipment the operator is made aware of expectations. An operator certification program is in the early stages of development. |
| Massachusetts | | | | | | |
| Michigan | As needed now (project engineers call).<br><br>10% verification in 2006. | 20-70 mph for high speed<br><br>8-12 mph for light weight | manual | Bounce test, block height, distance check. | Certify yearly by MDOT at test track in Lansing. | Most get manufacturer's training.<br>2006 will require operator certification. |
| Minnesota | - | Depends on device being used. | Cones. | Vertical calibration, bounce test, horizontal calibration. | Certified yearly at Minn Road Research facility in Albertville, MN. | Not required, although annual training class offered in April. |

| | *QC / QA* | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| Mississippi | Profilographs checked upon engineers request.<br>Inertial profilers checked every 6 months. | ≤ 3 mph for profilograph.<br>10-20 mph for lightweights.<br>Posted speed limit for high speed inertial profilers. | Manually for profilograph.<br>Reflective stripes or cones for inertial profilers. | Check for repeatability and reproducibility. | State-wide calibration sites. | Operators are certified during 6 month certification checks. |
| Missouri | Contractor QC. MODOT QA. | - | - | - | At a central site on a runway. | Technician certification. |
| Nebraska | | | | | | |
| Nevada | NDOT inspector on-site with data collection personnel. | 5 mph max. | N/A | Calibration @ beginning of project & as needed during collection. | On-site for each project. | None |
| New Hampshire | | | | | | |
| New Jersey | | | | | | |
| New Mexico | | | | | | |
| New York | Daily control section see attached MM 24.1.<br><br>NY DOT has Inertial Profiler Calibration and Verification methodology in place. | Equipment operable and safe speed. | Automatic or manual. | Daily calibration | Calibrated daily<br>Certified annually | See attached MM 24.1<br><br>NY DOT has Inertial Profiler Calibration and Verification methodology in place.<br><br>Each operator must successfully complete verification testing once per calendar year. |

| | QC / QA | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| North Carolina | | | | | | |
| North Dakota | NA | - | - | - | - | - |
| Ohio | | | | | | |
| Oklahoma | | | | | | |
| Oregon | None. Rely on manufacturer calibration process and proper filter setting to assure accuracy. | - | - | - | - | - |
| Pennsylvania | - | 5-15 mph | All used. | Distance checks. | Job site calibration. | Statewide performance certification. |
| Puerto Rico | Follow manufacturer's specifications for the test equipment. | 5-20 mph for LWP<br>We are in process to substitute the profilograph by the LWP. | Profilograph-manually<br>LWP-cones with reflective stripes. | System calibration (laser, longitudinal distance, bounce test) | We do not have a calibration verification and operator certification program for LWP. | Vendor's training. |
| Rhode Island | | | | | | |
| South Carolina | | | | | | |
| South Dakota | Normal walking speed. | - | Manually. | Height and distance calibration. | Calibrated on site. | - |
| Tennessee | | | | | | |

| | QC / QA | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q1a | Q1b | Q1c | Q1d | Q1e |
| Agency | What QC/QA processes are in place for data collection? | What is the acceptable range of speeds for your profiler equipment? | How is data collection triggered for your profiler equipment? | What types of profiler operational checks are performed? | Where are profilers calibrated and / or certified? | What type of training / certification do operators receive prior to operating a profiler? |
| Texas | QC data can be straight edge, profilograph or inertial profiler. | - | - | - | Profilers are calibrated by TTI Center. | Calibrated by TTI Center. |
| Utah | Annual calibration & onsite calibration use Dept. profilograph to check in case of suspect. | 3 mph | Reflective stripes<br>Cones | Manufacturer's calibration kit. | Not applicable yet. | Not applicable yet. |
| Vermont | Internal calibration | 20-65 mph | Manually or reflective strip(e). | Vendor specified. | Calibrate lasers for height only. | None |
| Virginia | - | >24 mph to posted speed limit | Cones & manual. | Manufacturer's recs. | State-established sites. | On-the-job. |
| Washington | - | 50-60 mph | Manually | DMI, Rutting and gyro pitch roll. | DOT lab and state patrol test track. | Vendor provided training. |
| West Virginia | No QC specified, QA by agency. | Any-all results calculated at 50 mph. | Reflective strips. | Sensor height, distance pulse, accelerometer, & bounce. | At LTPP Sites. | Manufacturers. |
| Wisconsin | | | | | | |
| Wyoming | Check performed to assure data saved correctly & in reasonable range. | 50 mph ± 2 or speed limit if lower. | Cones with reflective tape. | None. | Yearly at Department's test strip. | Certification for drivers required every 3 years from Department's class. |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| Alabama | - | - | - | - |
| Alaska | Repeat runs are performed to determine repeatability and compare w/ annual repeat runs.<br><br>Yes | Assume manufacturer's software is correct.<br><br>Supervisory review & peer review. | None required other than profiler operator training.<br><br>Learn equip software and perform ASTM E950 layout & equipment calibration. | No contractor equipment is available for ride.<br><br>No |
| Arizona | | | | |
| Arkansas | | | | |
| California | N/A | Engineer reviews contractor final data profilograph. | N/A | N/A |
| Colorado | - | - | - | - |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| Connecticut | Upper and lower allowable values. Values outside these are flagged. | Converting to Dayton Association Software. | Vendor training. | No contractor testing performed in CT. |
| Delaware | | | | |
| DC | | | | |
| Florida | | | | |
| Georgia | - | - | - | Yes |
| Hawaii | | | | |
| Idaho | | | | |
| Illinois | N/A | N/A | N/A | Not currently, possibly will change. |
| Indiana | | | | |
| Iowa | - | - | - | - |
| Kansas | - | - | - | Annual calibration certification. |
| Kentucky | - | - | - | - |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| Louisiana | A DOTD inspector will be present for the final test run and will immediately receive a copy of the results. | The Department may elect to perform and utilize independent ride quality test results for acceptance at any time. | This is provided by vendor's training course. An in-house certification training course is being developed currently. | Yes, annual certification process. |
| Maine | | | | |
| Maryland | QC data is sent electronically to the State and a computer program compares QC and QA data and provides a pay adjustment. | See Q2 above (previous question) | State review is performed by Engineer familiar with specifications and analyzed by computer program. Second review is performed before results are final. | Yes-It must compare favorably with data collected by other equipment on verifications sites. |
| Massachusetts | | | | |
| Michigan | Not much currently. | Not much currently. | Most have taken FHWA profiling class. | Must be calibrated if it won't certify. |
| Minnesota | - | - | Not required. | Must have a current year certification sticker. |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| Mississippi | None. | None. | NHI courses.<br>RPUG annual meeting. | Yes |
| Missouri | - | - | - | Yes, at least once per year. |
| Nebraska | | | | |
| Nevada | Review by DOT field office. | Review by DOT field office.<br><br>Manual checking of profiles with template. | None. | Yes, see above. (previous questions) |
| New Hampshire | | | | |
| New Jersey | | | | |
| New Mexico | | | | |
| New York | NY DOT has Inertial Profiler Calibration and Verification methodology in place.<br><br>Forms for calibration and verification processes. | DOT may run profile on our software to check IRI calculation. | Certification MM 24.1 | See MM 24.1<br><br>NY DOT has Inertial Profiler Calibration and Verification methodology in place. |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| North Carolina | | | | |
| North Dakota | - | - | - | - |
| Ohio | | | | |
| Oklahoma | | | | |
| Oregon | - | - | - | - |
| Pennsylvania | None | None | None | Yes |
| Puerto Rico | - | - | - | - |
| Rhode Island | | | | |
| South Carolina | | | | |
| South Dakota | - | - | - | - |
| Tennessee | | | | |

| | Q2 | Q3 | Q3a | Q4 |
|---|---|---|---|---|
| Agency | What QC/QA processes are in place for data handling? | What QC/QA processes are in place for data analysis? | What type of training / certification do analysts receive prior to processing / analyzing profile data? | Does contractor equipment have to undergo any calibration / verification testing? |
| Texas | - | - | Support by the Construction Division is provided to the Districts. | Yes |
| Utah | Engineering judgment | N/A | Operator's certification valid for 3 years. | Yes |
| Vermont | N/A | N/A | N/A | N/A |
| Virginia | Supervision oversight. | Supervision oversight. | On-the-job. | N/A |
| Washington | - | - | - | It is not envisioned at this time that contractor will be doing ride testing. |
| West Virginia | None at present. | Check manufacturers output with ProVAL software. | None | Not at present. |
| Wisconsin | | | | |
| Wyoming | Contractor turns in CD & raw data printouts to Engineer. | Verification testing performed by Department's profiler van and results compared. | Covered in Department's Training class. | Yes |

| | PROGRAMS | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? By how much? And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| Alabama | Yes | Yes | No | Adequate | Too early to tell | Perceived quality increase |
| Alaska | Yes | Yes | Yes<br>No, but pay incentive is doing this. | Functional but needs revision | Records show significantly smoother pavements | Records show better quality<br>Perceived quality increase |
| Arizona | | | | | | |
| Arkansas | | | | | | |
| California | Yes | Yes | No | Functional but needs revision | Unknown | Unknown |
| Colorado | Yes | Yes | No. Goals based on remaining service life. | Adequate | Too early to tell | Perceived quality increase |

| | PROGRAMS | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? By how much? And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| Connecticut | Yes | Yes | No | Functional but needs revision | Unknown | Unknown |
| Delaware | | | | | | |
| DC | | | | | | |
| Florida | | | | | | |
| Georgia | Yes | Yes | - | Adequate | Not applicable | Not applicable |
| Hawaii | | | | | | |
| Idaho | | | | | | |
| Illinois | Yes | Yes | No | Adequate<br>The 0.00 inch blanking band special provision is being reviewed on a regular basis and modified accordingly. | Records show significant smoother pavements | Too early to tell<br>Roads seem smoother initially; however, long term benefits still not determined because program is too new for the 0.00 inch blanking band. |
| Indiana | | | | | | |
| Iowa | Yes | Yes | No | Functional but needs revision | Records show significant smoother pavements | Unknown |
| Kansas | Yes | Yes | KDOT uses an overall performance level that is highly dependent on ride. Stated goals are at least 80% of the system must be in good condition and no more than 5% poor. KDOT has exceeded these goals since 1993. They roughly can be interpreted as 80% with IRI less than 105 in/mi and 5% within IRI greater than 165 in/mi. | Adequate | Records show significant smoother pavements | Perceived quality increase |
| Kentucky | Yes | Yes | - | Functional but needs revision | Records show significant smoother pavements | Records show better quality |

| | PROGRAMS | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? By how much? And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| Louisiana | Yes | Yes<br>(0.10 mile increments) | Yes<br>Recognition awards have been assigned recently for the best ride (smoothest) pavement for both concrete and HMAC paving jobs in Louisiana. | IRI just implemented and may need revisions based on pilot projects experience. | Unknown at this time, however it is positively anticipated. | Unknown at this time, however it is positively anticipated. |
| Maine | | | | | | |
| Maryland | Yes | Yes | Yes<br>to 83% or better<br>Maintain indefinitely. | Adequate | Too early to tell | Perceived quality increase<br><br>We definitely have an improved understanding of the issues. Contractors have refocused on good paving practices to achieve smooth pavements. |
| Massachusetts | | | | | | |
| Michigan | Yes | Yes | Ride is currently not used for decision making. Distress used instead. | Functional but needs revision | Records show significant smoother pavements<br><br>Was working until we stopped using incentives. | Unknown<br><br>An unbalanced incentive program (such as incentives on ride only) can have a negative effect on other pavement properties (density for instance). |
| Minnesota | Yes | Yes | Yes<br>Goals<br>70% of principal art w/PSR> 3.0, 2% or less w/PSR <=2.0<br>65% of minor art w/PSR> 3.0, 3% or less w/PSR <=2.0<br>60% of collector w/PSR> 3.0, 5% or less w/PSR <=2.0 | Functional but needs revision | Records show significant smoother pavements | Perceived quality increase |

| | PROGRAMS | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system?<br>By how much?<br>And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| Mississippi | Yes / No<br>Contractor collects network, Agency does 5% random sample to QA contractor's data. | Yes / No<br>Contractor collects network, Agency does 5% random sample to QA contractor's data. | No | Inadequate<br>Want to go to IRI based acceptance once the bump / dip & grind simulation based on IRI is addressed. | Unknown | Unknown |
| Missouri | Yes | - | No | Adequate | Records show significant smoother pavements | Perceived quality increase |
| Nebraska | | | | | | |
| Nevada | Yes<br>High speed profiler | Yes | Not that I'm aware of. | Adequate<br>Other: Based on certain categories Nevada has received recognition for the smoothest roads in the nation. | -<br>Somewhat smoother pavements. | Perceived quality increase<br><br>Better attention is paid in trying to obtain incentives. |
| New Hampshire | | | | | | |
| New Jersey | | | | | | |
| New Mexico | | | | | | |
| New York | Yes | Yes | No | Other: Still under development | Records show significant smoother pavements | Records show better quality |

| | *PROGRAMS* | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? By how much? And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| North Carolina | | | | | | |
| North Dakota | Yes<br>Use high speed for this. | Yes<br>Use high speed for this. | Yes<br>10%<br>2008. | Functional but needs revision | No difference in pavement smoothness<br>Only on PCC pavement. | No difference |
| Ohio | | | | | | |
| Oklahoma | | | | | | |
| Oregon | Yes | Yes | - | Inadequate | Too early to tell | Records show better quality |
| Pennsylvania | Yes | Yes | Yes | Adequate | Records show significant smoother pavements | Records show better quality |
| Puerto Rico | Yes | Yes | Yes, on the national highway system (NHS).<br>To reach the national standard IRI for the NHS.<br>Not date established. | Functional but needs revision | Unknown | Too early to tell<br>Unknown |
| Rhode Island | | | | | | |
| South Carolina | | | | | | |
| South Dakota | Yes | Yes | No | - | Records show significant smoother pavements | Perceived quality increase |
| Tennessee | | | Not a published goal, but an "expected" goal to make all routes very smooth. | Adequate | Too early to tell<br>This is first year in effect. | Records show better quality |

| | PROGRAMS | | | | | |
|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
| Agency | Does your agency collect ride data on the agency highway system for pavement management? | Does your agency collect ride data for HPMS? | Has your agency set a goal for increasing the percentage of pavements with an acceptable ride quality on its highway system? By how much? And by when? | How does your agency feel about its current specifications? | What have been the results of having incentive / disincentive program on initial pavement smoothness? | What have been the results of having incentive / disincentive program on material / construction quality control? |
| Texas | Yes | Yes | 90% of the network with a condition score >96. | Adequate | Records show significant smoother pavements | Records show better quality |
| Utah | Yes | Yes | Yes.<br>Maintain goal 90% interstate highways, 70% arterials, 50% collectors--Has already been achieved. | Adequate<br>Other: Considering use of high speed profiler. | Records show significant smoother pavements | Records show better quality<br><br>Contractors used Material Transport Vehicle (MTV) on large construction projects. |
| Vermont | Yes<br>Through a vendor contract. | Yes<br>Use data collected by our vendor. | FHWA specified. | Adequate | Not applicable<br><br>Not considered. | Not applicable |
| Virginia | No<br>No formal program | Yes | No | Adequate<br>Functional but needs revision | Records show significant smoother pavements<br>Too early to tell | Perceived quality increase |
| Washington | Yes | Yes | No, ride is not the more critical measure for evaluating the preservation program. | Other: Not yet implemented. | Too early to tell | Perceived quality increase |
| West Virginia | Yes<br>By consultant. | Yes<br>By consultant. | No | Other: Being revised. | Slight improvement | Not applicable |
| Wisconsin | | | | | | |
| Wyoming | Yes<br>Contractor does network data collection for PMS. | Yes<br>Contractor gathers this also. | No | Adequate | Records show significant smoother pavements | Not applicable |

| Agency | Q7<br>What have been the results of having incentive / disincentive program on overall cost to your agency? | Q8<br>What are the issues facing your agency with its current ride specification? | Q9<br>Does your agency or contractor collect profile data for acceptance? | Q10<br>Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Q11<br>Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | Q12<br>What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
|---|---|---|---|---|---|---|
| Alabama | Unknown | Using rideability specification on more projects. Should computerized profilographs be allowed on ALDOT project? Study the use of high speed or light weight profilers for job control. | Contractor collects<br>Agency reduces | No | No | - |
| Alaska | Unknown<br><br>No difference<br>Contractors use incentives to lower bid price. | -<br><br>Developing urban ride quality on roads having curb and gutter sections. | Agency | Yes | 50k maximum penalty, 50k max bonus<br><br>Yes | An evaluation outside of agency of effectiveness of specifications. Ride quality/smoothness has definitely improved.<br><br>- |
| Arizona | | | | | | |
| Arkansas | | | | | | |
| California | Unknown | Placing it on appropriate projects, fairness, different indices for AC & PCC. | Contractor | Not applicable | N/A | With specs, it's deciding what criteria to use for deciding what projects to put it on.<br><br>With testing, when we got to inertial profilers; reproducibility, calibration & data analysis().<br><br>Administrative-its what is a reasonable incentive/disincentive. |
| Colorado | Unknown | Switching to IRI from PI | Contractor | Yes | No | IRI bump finding and correction. |

| Agency | Q7<br>What have been the results of having incentive / disincentive program on overall cost to your agency? | Q8<br>What are the issues facing your agency with its current ride specification? | Q9<br>Does your agency or contractor collect profile data for acceptance? | Q10<br>Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Q11<br>Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | Q12<br>What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
|---|---|---|---|---|---|---|
| Connecticut | Unknown | Would like to implement use of light weight profilers and their use by contractors for quality assurance. But are waiting for results of pooled fund study TPF-5 (063) "Improving the Quality of Pavement Profile Assessment." | Agency | No | No | CT's goal is to reduce amount of testing performed by agency. |
| Delaware | | | | | | |
| DC | | | | | | |
| Florida | | | | | | |
| Georgia | Not applicable | - | Agency | Not applicable | N/A | - |
| Hawaii | | | | | | |
| Idaho | | | | | | |
| Illinois | Significantly higher payments<br>Higher payments in incentives with bituminous overlays, but have revised the special provision to reflect the PI vales that were typical for construction. | Getting equipment verified that Contractor results are accurate. | Agency<br>Contractor | No | Not at the present time. | Review equipment verification and trained tester requirements. |
| Indiana | | | | | | |
| Iowa | Unknown | Need updating to current "state of practice" of other states. | Yes<br>Agency<br>Contractor | No | Yes, max incentive or total remove and replace. | Same as Q8.<br>Need updating to current "state of practice" of other states. |
| Kansas | - | None | Contractor | No | No | None |
| Kentucky | Significantly higher payments | As PCC & AC pavement specifications differ, there are industry concerns. PCC industry has concerns with high speed profilers. | Agency | No | Yes | - |

| | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 |
|---|---|---|---|---|---|---|
| Agency | What have been the results of having incentive / disincentive program on overall cost to your agency? | What are the issues facing your agency with its current ride specification? | Does your agency or contractor collect profile data for acceptance? | Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
| Louisiana | Unknown at this time, however it is positively anticipated. | (referring to IRI specifications and systems)<br>Gaining familiarity with the IRI concept<br>Developing procedures to resolve disputes<br>Manufactures/equipment selection<br>Standardization of processing software | Yes | No | Yes, defined in Table 502. | Implementation of IRI specification for PCC pavements, further refinement of specs based on field experience. |
| Maine | | | | | | |
| Maryland | No difference | Operator and profiler certification (incl. baseline or reference profiles); concrete pavement and timing; How to allocate future resources to continue QA data collection and processing pay adjustments. Increasing data collection reliability so that QA can be reduces to a more reasonable level. | Contractor collects data with agency QA checks. | Yes<br>If approved by the agency construction project engineer (with some limitations). | Yes, the maximum amount (disincentive and incentive) is the values given in Q8 on page 6 multiplied by the total number of lane miles on the project. | Greater training and experience for construction personnel (agency inspectors and contractor's operators). Improved Data Reliability. Creating travel speed specific indexes (probably 3) so that measured smoothness value better reflects user needs. |
| Massachusetts | | | | | | |
| Michigan | No difference<br>Unknown<br><br>Bid prices about the same. Value of added performance due to smoother roads is unknown. | New 2006 Spec (to be shadowed in 2005) will require 10% verification and a switch to IRI. Profile index will be eliminated as soon as the texture use with lasers is resolved. | Contractor | No<br>An old spec allowed this and it led to a lot of grinding. | N/A | National standards on filters, and sample rates. |
| Minnesota | Too early to tell | Thinking of going to 0.0 inch blanking band and/or IRI. | Contractor | Yes | See attached paragraph under C6 payment.<br><br>From C6 Payment, the total ride incentive shall not exceed 10% of the total mix price for 3 lift construction and 5% of total mix price for 2 and 1 lift construction.<br><br>Another item is that the contractor will not receive a net incentive payment for ride if more than 25% of all density lots for the project fail to meet minimum density requirements. | Be sure to certify equipment on same index that is used for payment. Do not certify equipment on zero blanking band and pay on 0.2 inch blanking band. |

| | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 |
|---|---|---|---|---|---|---|
| Agency | What have been the results of having incentive / disincentive program on overall cost to your agency? | What are the issues facing your agency with its current ride specification? | Does your agency or contractor collect profile data for acceptance? | Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
| Mississippi | Unknown | 1. Bridges with no approach pavement.<br>2. Must grind location is difficult with profilers. | Contractor | No<br>Can not get more than 100% pay on corrected section. | No | - |
| Missouri | No difference | None that we are aware of. | -<br>Contractor QC<br>MODOT QA | Contractor can correct to eliminate deducts. | - | - |
| Nebraska | | | | | | |
| Nevada | Significantly higher payments | No issues- See Q4 comment above. | Contractor collects data, NDOT reviews & accepts | Yes | Yes | None |
| New Hampshire | | | | | | |
| New Jersey | | | | | | |
| New Mexico | | | | | | |
| New York | Unknown | Don't have the resources to verify enough profilers. We are planning to help our industry start a for-fee verification program which we will accept as certification. | Yes | Yes<br>Pavement is remeasured after corrections and payment is adjusted. | See the specification.<br><br>As discussed in earlier questions, payment of Quality Units is based on the Index Price listed in the contract documents. | None |

| Agency | Q7<br>What have been the results of having incentive / disincentive program on overall cost to your agency? | Q8<br>What are the issues facing your agency with its current ride specification? | Q9<br>Does your agency or contractor collect profile data for acceptance? | Q10<br>Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Q11<br>Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | Q12<br>What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
|---|---|---|---|---|---|---|
| North Carolina | | | | | | |
| North Dakota | No difference | No ride specifications on AC pavement results in poor ride. | Agency, only on PCC pavements. | No | Yes, on PCC pavements only. | Incentive/Disincentive program on all types of pavement. |
| Ohio | | | | | | |
| Oklahoma | | | | | | |
| Oregon | Unknown | We will be switching to IRI during 04-05. | Contractor | No | No | Need certification program, need simpler administration-electronic data other than hard copy. Agency analysis of raw profile data. |
| Pennsylvania | - | Bridge ride quality, cost effectiveness of super smooth pavements-less than 35. | Contractor | Yes | No | - |
| Puerto Rico | Too early to tell<br>Unknown | 1. Substitute profilograph for the LWP<br>2. Education process to inspector, project administrator and others about the smoothness specifications<br>3. Improving the criteria to assign the spec's | Agency | Yes<br>But it's for a credit. | - | Feedback from construction personnel about lessons learned in the field. Fine-tuning the test section and lots of production for contractor's PI evaluation. |
| Rhode Island | | | | | | |
| South Carolina | | | | | | |
| South Dakota | No difference | Application in urban environments. | Contractor | No | No | Comparing with light weight. |
| Tennessee | No difference | None | Agency | No | No, other than max% by specs. | None |

| Agency | Q7<br>What have been the results of having incentive / disincentive program on overall cost to your agency? | Q8<br>What are the issues facing your agency with its current ride specification? | Q9<br>Does your agency or contractor collect profile data for acceptance? | Q10<br>Is the contractor allowed to correct any profile defects in order to receive incentive pay? | Q11<br>Is there a cap to how much money a contractor can earn in incentive and lose in disincentives? | Q12<br>What general improvements are needed with respect to pavement smoothness specifications, testing and administrative procedures? |
|---|---|---|---|---|---|---|
| Texas | Unknown | - | Contractor<br>Bu we can verify it if needed. | Yes<br>IRI>95 or localized roughness. | No | - |
| Utah | No difference<br><br>Competitive bid system results in low bid from good contractors. | Toying to implement high speed profiler. Dept has only one equipment. | Contractor collects, Agency accepts. | Yes | No | Calibration process for high speed profiler in profilograph PI mode and IRI mode. |
| Vermont | No difference | None at this time. | No | Yes | Function of IRI | Waiting to monitor more research. |
| Virginia | Too early to tell | Incentive/disincentive sizes, selection of suitable sites. | Agency | No | No, well 10% bid is max bonus. | See Q8. Would like to incorporate uniformity & roughness profiles and PWL. |
| Washington | Unknown | Uniform implementation statewide. | Agency | No<br>Required to correct deficiencies, but can not grind full width to improve incentive. | No | - |
| West Virginia | No difference | Disliked by contractor. They want QC spelled out and to be allowed to do QA. Also, incentive program. | Agency | No | No | Remove unit bid price from disincentive calculations and require qualified operators and certified equipment as per AASHTO. |
| Wisconsin | | | | | | |
| Wyoming | No difference | Pay curve may need adjustment due to large numbers of bonuses given out. | Contractor | Yes | No | Curve adjustment possibly. |

# APPENDIX C. REVISED MDT RIDE SPECIFICATION

# RIDE SPECIFICATION FOR FLEXIBLE PAVEMENT (REVISED 06/2006)

## 1.0 CONSTRUCTION REQUIREMENTS:

Construct all surfacing courses to provide completed plant mix bituminous pavements that meet surface smoothness levels derived from the International Roughness Index (IRI) for a Category (1 or 2) project and that meet the surface profile requirements of the finished surface. Surface smoothness and surface profile will be analyzed from data collected by the Department using a Class I Laser Road Profiler following various MDT procedures pertaining to profiler operations.

## 2.0 SURFACE SMOOTHNESS:

Target IRI values are determined by project category based on the opportunities for improving the ride, by the pre-pave IRI, or by a combination of both as follows:

*Category 1 Projects:*

Target IRI set at 50 to 55 in/mi (0.79 to 0.87 m/km).

Project with two or more opportunities to improve the ride or

Single lift overlays with pre-pave IRI < 110 in/mile (1.74 m/km).

*Category 2 Projects:*

Target IRI set at 55 to 60 in/mi (0.87 to 0.95 m/km).

Single lift overlays with pre-pave IRI value ≥ 110 in/mi (1.74 m/km) and < 190 in/mi (3.00 m/km).

*Exception for High Pre-Pave IRI Roadways*

Roadways with pre-pave IRI values above 190 in/mi (3.00 m/km) will be treated as a Category 1 project with two or more opportunities to improve the ride. However, if for other reasons (i.e., budgetary) only one opportunity is reasonable and/or feasible then MDT will specify a maximum post pave IRI should not be more than 50% of the pre-pave IRI. For these cases, there will be no pay adjustment factor based on smoothness; however, corrective actions need to be taken at contractor's expense if post paving IRI is greater than 50% of pre-paving IRI.

Each opportunity to improve the ride is one of the following:

- Placing a gravel base or surfacing course,
- Placing plant mix bituminous base,
- Placing cement treated base,
- Placing pulverized plant mix surfacing,
- Milling,
- Cold recycling (milling and laydown), or
- Each full 0.15 ft (45 mm) increment of new plant mix surfacing.

## 3.0 SURFACE PROFILE:

Correct surface profile defects that fail the bump criteria of 0.40 inches (10 mm) in a distance of 25 ft (7.62 m) within 30 calendar days of notification but prior to seal and cover operations. Correct surface profile defects by milling and filling deficient pavement depths or by diamond grinding excess pavement depths. Corrected surface profile defects will be retested and evaluated. Pavement thickness will be measured after profile corrections are made. Ensure corrected pavements do not create a transverse height difference between adjacent lanes exceeding 1/8 inch (3 mm). Fog seal corrected areas in the roadway if not chip sealed prior to winter shutdown.

## 4.0 TESTING & ACCEPTANCE:

The Department will test for surface smoothness and surface profile prior to placement of seal and cover on the final lift of plant mix bituminous surfacing pavement. Data collected for each wheel path will be averaged for that lane. Tests will be performed within three working days (extended by rain or other weather conditions) of completion of all paving. The Department will test divided highways within three working days (extended by inclement weather condition) of completion of paving for each direction of travel. The contractor must ensure that the entire finished lane width can be tested and is not impeded to Department personnel at the time of testing. Test results will be furnished within two working days.

If the entire final lift of pavement cannot be completed before winter shutdown, data will be collected for all roadway sections paved through the final lift. Evaluation of the remaining pavement will be performed once the paving is completed.

*Courtesy Testing*

Provide at least seven calendar days notice to the Project Manager to obtain a courtesy test. The Department will provide courtesy smoothness and surface profile tests once per project, on not less than 2 and not more than 3 miles (on not less than 3.2 and not more than 4.8 km) of continuous new pavement. Courtesy test results are informational only. The contractor interprets the courtesy test results and determines the impact to the work. The Department will perform separate tests for acceptance evaluation.

*Surface Smoothness*

The surface smoothness analysis will be used to determine the actual IRI for calculating pay factors for the entire plan depth of bituminous mix section placed in this contract.

Actual IRI values will be determined on all mainline travel lanes including climbing lanes, passing lanes, and ramps that are 0.2 miles (0.32 km) or longer. Bridge decks will be included only if they are paved as part of the project.

Smoothness data will not be evaluated for the following roadway sections:

- Climbing and passing lanes, less than 0.2 miles (0.32 km),
- Turning lanes,
- Acceleration and deceleration lanes,
- Shoulders and gore areas,
- Road approaches,
- Horizontal curves 900 ft (274.32 m) or less in centerline radius and pavement within the superelevation transitions of these short radius curves, or

– Pavement within 50 ft (15.24 m) of bridge decks (only for bridges not paved as part of the project), approach slabs, and the terminal paving points of the project.

*Surface Profile*

Areas requiring corrective work will be identified using the surface profile measurements of the finished surface. All areas not tested for surface profile under this provision are to meet the requirements in Specification Subsection 401.03.14 Surface Tolerances.

*Measurement*

The surface smoothness will be measured using the International Roughness Index (IRI). The surface smoothness will be evaluated by section. A section is defined as a single paved lane; 12 feet (3.66 m) wide or greater, 0.20 miles (0.32 km) long. Partial sections will be prorated or added to an abutting section.

Tables C-1 and C-2 present the category pay adjustment factors will be applied to each section:

*Table C-1. Category 1 Pay Adjustment Factor Relationship.*

| IRI (in/mi)<br>[m/km] | Pay Adjustment Factor# |
|---|---|
| < 35<br>< [0.55] | 1.25 |
| 35 – 50<br>[0.55 – 0.79] | 1.845 – 17/1000 * IRI |
| 50 < IRI <55<br>[0.79 < IRI < 0.87] | 1.00 |
| 55 – 75<br>[0.87 – 1.18] | 1.825 – 3/200 * IRI |
| 75 < IRI <90<br>[1.18 < IRI < 1.42] | 0.70 |
| > 90<br>> [1.42] | Corrective Action Required<br>(Initially Assumed as a Zero Pay) |

*#Use only US Customary Units with pay adjustment factor relationships.*

*Table C-2. Category 2 Pay Adjustment Factor Relationship.*

| IRI (in/mi) | Pay Adjustment Factor# |
|---|---|
| < 50<br>< [0.79] | 1.10 |
| 50 – 55<br>[0.79 – 0.87] | 2.100 - 1/50 * IRI |
| 55 < IRI <60<br>[0.87 < IRI < 0.95] | 1.00 |
| 60 – 95<br>[0.95 – 1.50] | 1.343 - 1/175 * IRI |
| > 95<br>> [1.50] | Corrective Action Required<br>(Initially Assumed as a Zero Pay) |

*#Use only US Customary Units with pay adjustment factor relationships.*

5.0 BASIS OF PAYMENT:

*Surface Smoothness*
This is a Class ____ project. The pay factor will be applied to the unit price for each type of plant mix surfacing placed in each section. Calculate the quantity of the surfacing for each section as follows:

(L x W x D) x Unit Weight

Where:
L = Length of the lot measured.
W = Width of the travel lane measured.
D = Depth of the entire bituminous surfacing section placed under this contract**.

Unit Weight = 98% of mix design bulk density for each type of bituminous surfacing (When accepting density with nuclear gauge).

Unit Weight = 93% of Rice Gravity from the mix design for each type of bituminous surfacing (When accepting density by core method).

**Where different types of bituminous surfacing are used on successive lifts, the pay factor is applied separately to each type of surfacing.

Incentives for sections that qualify for a pay factor greater than 1.00 will be reduced based on the number of density tests that do not meet minimum plant mix pavement density requirements as shown in the Ride Incentive Reduction Table (C-3) below.

*Table C-3. Ride Incentive Reduction.*

| Project Size | % of Density Tests Not Meeting Specifications | | |
|---|---|---|---|
| | No Reduction of Ride Incentive | Incentive Reduced | No incentive Allowed |
| 0 to 25,000 Tons | 0 to 10 % | % Failing Tests * 8 - 60 | 25% |
| > 25,000 Tons | 0 to 5 % | % Failing Tests * 6.67 - 33.33 | 20% |

If more than 10% of the ride sections are subject to price reductions, no other sections will qualify for a pay factor greater than 1.00.

Price reductions will be calculated using the greater of the Contract Bid Price or base unit price for the grade of Plant Mix Bituminous Surfacing specified in the contract.

For Category 1 roadways and for any segment with a post-pave IR greater than 90 in/mi (1.42 m/km), the contractor is required to remove and replace the segment by milling 0.15 feet (3.81 mm) and replacing with new material meeting the original contract requirements. The maximum pay adjustment factor possible for the affected segment after corrective action is taken will be 1.0.

For Category 2 roadways and for any segment with a post-pave IR greater than 95 in/mi (1.50 m/km), the contractor is required to remove and replace the segment by milling 0.15 feet (3.81 mm) and replacing with new material meeting the original contract requirements. The maximum pay adjustment factor possible for the affected segment after corrective action is taken will be 1.0.

All work to prepare the roadway for testing, including but not limited to sweeping, is incidental to the work and is not measured for payment. Include all cost and resources to prepare the roadway for surface tolerance testing in the Plant Mix Bituminous Surfacing bid item. Requests for additional compensation by reason of this provision will not be considered nor allowed.

# APPENDIX D.  REVISED MT-422

# METHODS OF SAMPLING AND TESTING
# MT-422
# METHOD OF TEST FOR SURFACE SMOOTHNESS AND PROFILE

## 1. SCOPE

1.1. This method covers the testing of a finished flexible pavement surface for smoothness and profile. The surface smoothness is expressed in International Roughness Index (IRI) in units of inches per mile. The surface profile is generated to locate variations in profile (e.g., bumps or dips). This method is not intended to be used with rigid pavement or gravel surfacing.

## 2. REFERENCE DOCUMENTS

2.1. MDR 4080/4097 Mobile Data Recorder (MDR) Operation Manual, International Cybernetics Corporation.

2.2. Profiler Operations Manual (POM) for MDT Profilers (most recent version).

2.3. MDT QC/QA Plan (most recent version).

## 3. TERMINOLOGY

3.1. International Roughness Index (IRI) – An index resulting from a mathematical simulation of vehicular response to the longitudinal profile of a pavement using a 'quarter-car' simulation model as described in NCHRP Report 228.

## 4. APPARATUS

4.1. Class I laser road profiler as defined in ASTM E950. The road profiling system is mounted on a vehicle, usually a van or truck. It consists of the following components:

4.1.1. A vertical non-contact height measurement system (i.e., laser) capable of measuring the height from the mounted sensor face to the surface of the pavement.

4.1.2. A linear distance measuring system (i.e., DMI) capable of measuring distance traveled.

4.1.3. An inertial referencing system (i.e., accelerometers) capable of measuring the movement of the vehicle as it traverses the pavement.

## 5. SOFTWARE

5.1. The software must activate the testing using parameters (i.e., data collection initiation) that are stored by the control setup.

5.2. The software must receive, display, and store raw data received from the profiler.

5.3. The software must be able to accumulating desired output and printing results.

6. CALIBRATION

6.1. A comprehensive calibration and sensor check should be performed at an interval of thirty (30) days during construction season.

6.2. Calibration is used to establish and adjust the operating characteristics of the MDR system. There are four items that will either be calibrated or checked: laser sensors, accelerometers, bounce test, and DMI.

6.3. Laser Sensor Check

6.3.1. The laser sensors have been calibrated in the factory and the operator cannot truly calibrate these sensors.

6.3.2. A calibration check of the laser sensors is performed prior to data collection.

6.3.3. A full calibration check of the laser sensors must also be performed whenever problems are suspected on the laser sensors, or when a sensor is repaired or replaced.

6.3.4. Facility

6.3.4.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.3.4.2. Facility should have level surface and be free of any vibration.

6.3.5. Procedures

6.3.5.1. Calibration check should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.3.5.2. Check Sensor Height: Make sure the laser sensors are powered off. Remove sensor covers. Measure distance from floor to glass face of the laser sensor. This distance should be within 13 in ± 0.5 in (330 mm ± 10 mm). The distance from ground to face of the sensor should not change between calibration checks that are performed monthly, unless sensors have been moved or replaced since the previous calibration check. Adjust sensor if required so that height from glass face of sensor to ground is 13 in ± 0.5 in (330 mm ± 10 mm).

6.3.5.3. The operator should be outside of the profiler when the calibration check is performed. Adjust the computer monitor so that it can be seen from outside the vehicle, and the keyboard should be placed on the seat of the profiler. Do not enter the profiler, bounce or bump the profiler, or lean on the profiler during the calibration check.

6.3.5.4. Record the actual ¼”, ½”, and 1” calibration block thicknesses (in English Units) in the Profiler Calibration Record Sheet.

6.3.5.5. Verify that no blocks, objects, or debris are directly under the laser sensors. From the Sensor Calibration Screen, record the left laser (sensor 1) Height value for the floor height measurement in the appropriate space on line 2 (Height: Floor) in the Profiler Calibration Record Sheet.

6.3.5.6. Place the ¼” calibration block on the floor under the left laser sensor, and position the block so that the laser will reflect approximately at the center of the block. From the Sensor Calibration Screen, record the left laser (sensor 1) Height value for the block height measurement in the appropriate space on line 3 (Height: Block) in the Profiler Calibration Record Sheet.

6.3.5.7. Remove the calibration block from under the left laser sensor and verify the Height value on the Sensor Calibration Screen is the same as the value recorded in step 6.3.5.5.

6.3.5.8. Repeat steps 6.3.5.6 and 6.3.5.7 using the ½" and 1" calibration block.

6.3.5.9. Using the Height values recorded in the Profiler Calibration Record Sheet, compute the "Height: Floor - Block" values for each of the ¼", ½", and 1" calibration blocks by subtracting the "Height: Block" value from the "Height: Floor" value.

6.3.5.10. Using the "Height: Floor - Block" values recorded in the Profiler Calibration Record Sheet, compute the "Difference: Actual - Height" values for each of the ¼", ½", and 1" calibration blocks by subtracting the "Height: Floor - Block" value from the "Actual Block Thickness" value.

The computed value should be less than or equal to 0.002 ft for the laser sensor to be considered working properly. If the value is greater than 0.002 ft, the trouble shooting procedure below is a suggested guide to verify and resolve any issues with the laser sensor.

6.3.5.11. Repeat previous steps to perform the laser sensor calibration check on the right laser (i.e., sensor 2).

6.3.5.12. If any of the "Difference: Actual – Height" values computed for the left and right sensors are greater than 0.002 ft, the following items are suggested to verify that there is an actual problem with the laser sensor. If these procedures do not successfully rule out a problem with the laser sensor(s), ICC should be contacted to assist and resolve sensor problems.

Verify that all recorded values and computations are accurate.

Repeat the laser sensor calibration check for the block(s) and laser that produced an unacceptable difference greater than 0.002 ft. It is possible that the block was not positioned under the laser sensor properly, or that the block was not sitting squarely on the floor. It is not necessary to repeat the calibration check for any blocks that satisfy the acceptable criteria.

If the laser sensor calibration check was performed with the engine running, attempt to perform the calibration check (in its entirety) with the engine switched off and the profiling system plugged into house power (if possible).

Move the profiler to another location and redo the laser sensor calibration check in its entirety.

6.4. Accelerometers

6.4.1. Accelerometers in the profiler should be calibrated if the accelerometer check indicates accelerometer calibration factor(s) are outside the allowable range. The accelerometers should be calibrated when repairs are performed on the accelerometer(s) or on computer cards associated with the accelerometer(s). The accelerometers should be calibrated at the time a full calibration check is performed on the laser sensors.

6.4.2. Facility

6.4.2.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.4.2.2. Facility should have level surface and be free of any vibration.

6.4.3. Procedures

6.4.3.1. Calibration should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.4.3.2. Calibration of accelerometers should not be performed when the engine of the profiler is running.

6.4.3.3. Operator should be outside of vehicle when calibration is performed.

6.4.3.4. Operator should adjust computer monitor so that it can be seen from outside vehicle and keyboard should be placed on seat of profiler.

6.4.3.5. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration.

6.4.3.6. The power to the system should have been turned on for about 15 minutes for the system to warm up prior to calibrating the accelerometers.

6.4.3.7. Proceed to Accelerometer Calibration Menu and begin collecting data. After approximately 2000 samples, end calibration.

6.4.3.8. System will prompt the operator if the new Accelerometer Calibration Factor (ACF) values should be accepted. The accelerometers are considered to be working properly if the ACF values are within the range 512 ± 10. If test appears to be valid, accept the values. If test was not valid, repeat the calibration procedure.

6.5. Bounce Test

6.5.1. The bounce test is a controlled-conditions procedure that uses the profiler's built in simulation capabilities to test that the profiling system is operating properly.

6.5.2. Facility

6.5.2.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.5.2.2. Facility should have level surface and be free of any vibration.

6.5.3. Procedures

6.5.3.1. Place a brown wooden clipboard on the ground directly under the right and left laser sensors so that the lasers spots are near the center of the clipboards. Metal, plastic, or colored clipboards are not recommended as the intent of the clipboards is to have the laser sensor take height measurements off a flat neutral colored surface.

6.5.3.2. Verify that the "Reference Post Display Mode" is set to "Mile".

6.5.3.3. Set the "Asc/Dsc Ref Point" to "+".

6.5.3.4. Highlight the "DMI Simulator" option and press 'Enter' key to toggle the distance simulator to "On".

6.5.3.5. Begin simulation and verify that the "Speed" indicates a reasonable simulated speed. If the indicated speed is zero, exit the run screen and verify that the distance simulator is turned on.

6.5.3.6. Initiate the reference reset. The profiler should remain settled for the static portion of the bounce test for a minimum of 0.5 miles (0.80 km) indicated on the "Reference Post."

6.5.3.7. After the "Reference Post" indicates a minimum of 0.5 mi (0.80 km), the operator should begin to apply a vertical up and down motion to the center of the sensor bar on the front of the profiler. The pitching motion on the sensor bar should impart a displacement of approximately 1 in total. All efforts should be attempted to avoid any side to side or rolling motions. This dynamic portion of the bounce test should continue, without interruption, for a minimum of 30 seconds.

6.5.3.8. At the conclusion of the dynamic portion, mark the section end of the simulated profile and then stop the simulated profile.

6.5.3.9. Save the profile data file to the hard disk drive.

6.5.3.10. Create IRI report with interval of 100 ft (30.48 m).

6.5.3.11. Review the IRI report for Reasonableness.

The first 0.5 mi (0.80 km) of intervals on the report should contain IRI values reflecting the profiler in a static condition. The resulting static IRI values should be less than or equal to 5 in/mi (0.08 m/km) for the profiler to be considered functioning properly under static conditions. As long as no more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km) in either the left or right channels the profiler is considered to have satisfied the static bounce test criteria.

If more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km), the bounce test should be repeated to make sure that the profiler remained completely motionless (was not bumped, moved, or otherwise disturbed) during the static portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the static IRI values are not improved.

The intervals following the static portion represent the profiler in a dynamic condition and typically have IRI values much larger than the static condition IRI values. The dynamic IRI values would typically be in the range of 20 to 45 in/mi (0.32-0.71 m/km) for the amount of motion imparted following this bounce test procedure. If more than three intervals of dynamic IRI values are less than 20 in/mi (0.32 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test.

If a majority of intervals of dynamic IRI values are significantly more than 50 in/mi (0.79 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the dynamic IRI intervals are not improved.

Select one interval from the static portion of the bounce test and record the resulting IRI values for the right and left sensors in the appropriate blocks in the Profiler Calibration Record Sheet.

Select one interval from the dynamic portion of the bounce test and record the resulting IRI values for the right and left sensors in the appropriate blocks in the Profiler Calibration Record Sheet.

6.6. Distance Measuring Instrument (DMI)

6.6.1. DMI should be calibrated whenever problems are suspected. The DMI should also be calibrated when tires are replaced, suspension repairs are performed or when wheels are rotated or aligned. The DMI should be calibrated when repairs are performed on the DMI or to computer cards associated with the DMI.

6.6.2. Calibration Site

6.6.2.1. Each MDT District should have a calibration site established.

6.6.2.2. This site should be located on a straight portion of roadway that is reasonably level and has low traffic volume.

6.6.2.3. Speed limit at the site should be at least 50 mph (80 km/h).

6.6.2.4. This site should be in an area where the vehicle can be driven at a constant speed without interruptions.

6.6.2.5. The site should be measured with a standard surveying tape using standard surveying procedures, or laid out using an electronic distance measuring system.

6.6.3. Procedures

6.6.3.1. Calibration should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.6.3.2. The DMI is calibrated by driving the vehicle over a known distance to calculate the Distance Calibration Factor (DCF).

6.6.3.3. A total of six calibration runs are performed.

6.6.3.4. Acceptability of the DMI Calibration

This is determined by comparing the six "PULSE COUNT" values resulting from the six calibration attempts to the "PULSE COUNT" value in the "AV" row. All six calibration attempts should have values that are within ± 10 of the average pulse count. For example: If the average pulse count is 14047, then all six pulse counts from the six calibration attempts must be within 14037 and 14057.

If any of the six calibration attempts is outside the acceptable limits, then the unacceptable runs should be highlighted and deleted. Following the deletion of the unacceptable runs, new calibration attempts should be made for each run that was deleted. The intention is to only delete the poor runs and replace with new runs, and NOT re-run a complete set of 6 runs.

6.6.3.5. Save the new DCF value that was computed during DMI calibration.

6.7. Record Keeping

6.7.1. All calibration activities must be documented. Instruction and forms are provided in latest version of reference documents.

# 7. PROJECT TESTING

## 7.1. Preparation of Surface

7.1.1. MDT will test the roadway only when it is free of moisture and any deleterious material that would not provide accurate test results.

7.1.2. The Contractor is responsible for all work to prepare the roadway for testing, such as, but not limited to sweeping off of debris.

7.1.3. Testing will not be conducted while it is raining or under other weather conditions determined inclement by the Engineering Project Manager (EPM).

## 7.2. Project Setup

7.2.1. Meet with the Engineering Project Manager (EPM) or one of his/her representatives and identify the Beginning-of-Project (BOP), the End-of-Project (EOP), and all excluded areas (e.g., all bridges that were not paved as part of the project).

7.2.2. If possible, project should be marked for testing using reflective tape or reflective traffic cones. These markers are used to initiate and stop data collection.

7.2.3. If it is not feasible to use the photocell to initiate and stop data collection, data collection can be initiated and stopped manually. When manually initiating and stopping profile data collection, cones should be placed at the beginning and end of the project to be used as reference points by the operator.

7.2.4. Example project layout is provided in attached figure 1.

## 7.3. Profiler Operations

7.3.1. Operation of profiler should be consistent with guidelines discussed in the latest version of the MDT Profiler Operations Manual. This includes but is not limited to the following:

7.3.1.1. Establish one unit system.

7.3.1.2. If possible, initiate data collection via reflective surface and photocell.

7.3.1.3. Use approved file naming convention.

7.3.1.4. Document any issues that occurred during testing.

7.3.1.5. Process data with software.

7.3.1.6. Properly backup data.

7.3.1.7. Provide report to EPM or one of his/her representatives.

7.3.2. MDT collects two error free runs.

7.3.2.1. Once the operator is confident that a minimum of two error free runs have been obtained, the Quality Control Review and Bump Reports are used to evaluate their acceptability. Profiler runs should satisfy the following criteria:

7.3.2.1.1. The average IRI values at each 1 mi (1.61 km) interval for each of the two runs are within ± 5.7% of the mean IRI of both runs.

7.3.2.1.2. If spikes (e.g., unusually high IRI) are present in the data, the operator should determine if spikes are pavement related or the result of equipment or operator error. The operator should examine the profile bump reports for discrepancies and features that cannot be explained by observed pavement features.

7.4. Testing Results

7.4.1. Results shall be provided to EPM or one of his/her representatives and shall be processed into desired segments (e.g., 0.2 miles) as described in most recent Ride Specification.

7.4.2. A Roughness Report will be generated for the first profile run deemed to be error free for each lane profiled. This report will contain the IRI values for the left and right wheel paths. These IRI values will be applied to the most recent pay incentives/disincentives as described in Ride Specification.

7.4.3. A Bump Report will be generated for the first profile run deemed to be error free for each lane profiled. The Bump Report will indicate the locations of potential defects. These will be reviewed with the EPM. Location should be physically examined to determine if, at the EPM's discretion, the location should be considered a defect.

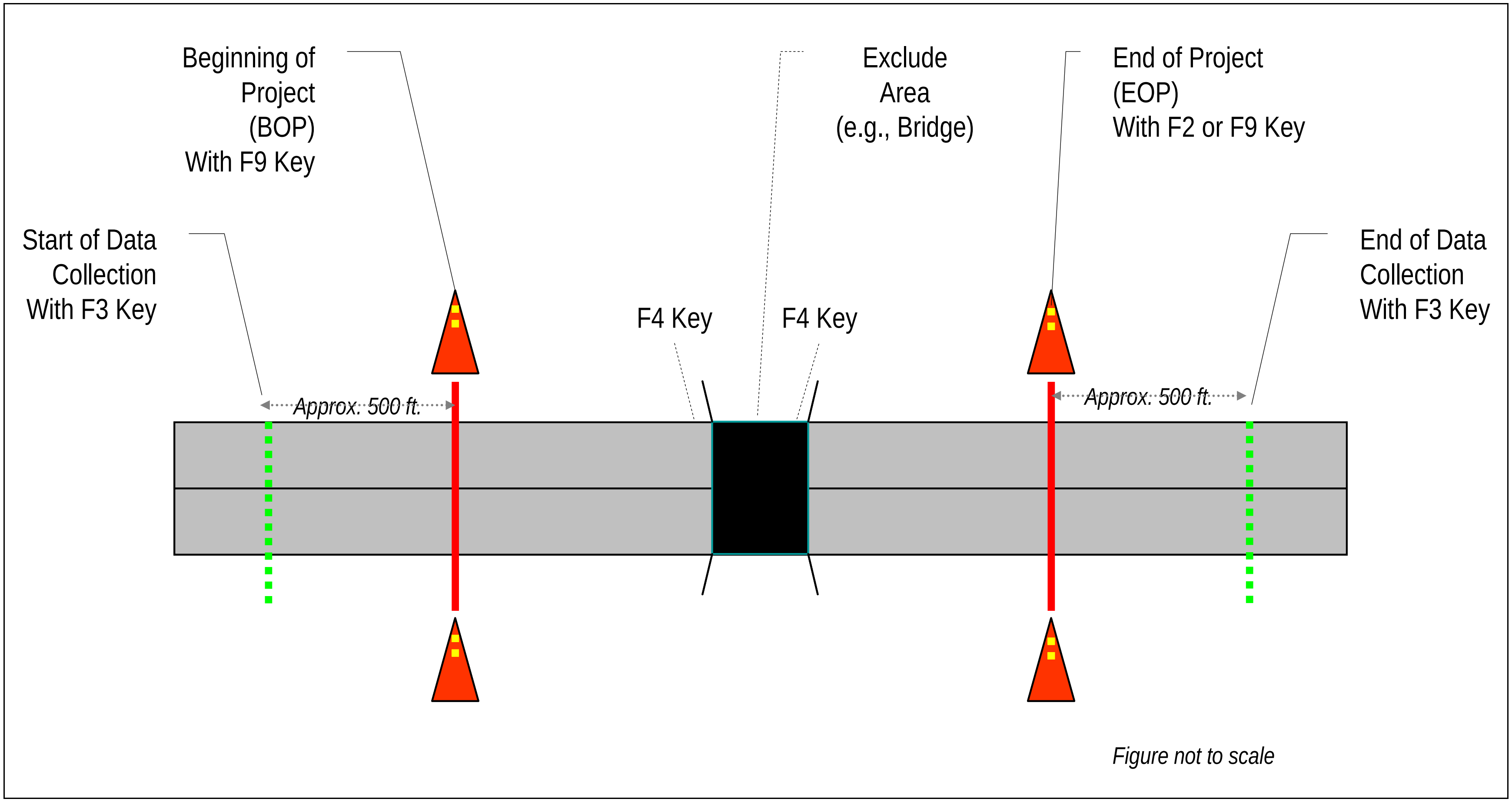


*Figure 1. Example of Project Layout.*

# APPENDIX E.  PROFILER OPERATIONS MANUAL

# PROFILER OPERATIONS MANUAL (POM) FOR MDT PROFILERS

JUNE 2006

Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

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## ACRONYMS

| | |
|---|---|
| AC | Alternating Current |
| ACF | Accelerometer Calibration Factor |
| AASHTO | American Association of State Highway and Transportation Officials |
| DC | Direct Current |
| DCF | Distance Calibration Factor |
| DMI | Distance Measuring Instrument |
| EDM | Electronic Distance Measurement |
| EPM | Engineering Project Manager |
| FGF | Filter Gain Factor |
| FHWA | Federal Highway Administration |
| HPF | High Pass Frequency |
| IBM | International Business Machine |
| ICC | International Cybernetics Corporation |
| IRI | International Roughness Index |
| LTPP | Long Term Pavement Performance |
| MDR | Mobile Data Recorder |
| MDT | Montana Department of Transportation |
| PCR | Pavement Condition Recorder |
| PMS | Pavement Management System |
| SCF | Sensor Calibration Factor |

# 1.0 INTRODUCTION

### *1.1 SIGNIFICANCE OF PAVEMENT RIDE MEASUREMENTS*

Longitudinal profile along the wheel paths of a pavement are used to evaluate its smoothness. Indices such as International Roughness Index (IRI) are computed and used for the pavement management system (PMS) as well as for construction surface smoothness specifications.

### *1.2 MDT RIDE DATA COLLECTION*

Ride data is collected using a profiler. Each MDT District operates a profiler to collect data within its district. MDT operates and maintains profilers from International Cybernetics Corporation (ICC). The model types used are Mobile Data Recorder (MDR) 4080 and 4097.

### *1.3 OVERVIEW OF THE MANUAL*

This manual describes procedures to be followed when measuring pavement profiles using the ICC MDR 4080 / 4097 inertial profilers. Additionally, this manual describes procedures to be followed when processing the data collected by this device.

The following items related to data collection are covered:

1. Equipment,
2. Calibration of equipment,
3. Data collection, and
4. Record keeping.

Format of this manual follows the FHWA LTPP Manual for Profiler Measurements and Processing, Version 4.1, May 2004.

# 2.0 ICC PROFILER

The ICC MDR 4080 / 4097 profiler is a modified truck that is equipped with specialized instruments to measure and record road profile data. The profiler contains two laser height sensors, an accelerometer coupled with each laser height sensor, a longitudinal distance measuring instrument (DMI), a computer system, data acquisition electronics, and power control equipment.

The two laser height sensors and accelerometers in the unit are mounted on a sensor bar that has been installed on the front of the vehicle. The longitudinal distance measuring system receives a signal from the truck's speed sensor on the differential of the vehicle and measures the distance traveled by the profiler.

Data recorded by the height sensors, accelerometers and DMI are stored in the computer memory (and later stored to hard disk). These data can be processed to obtain the profile along the path that was traversed by each sensor.

According to ICC, the profiler can measure road profiles at speeds ranging from 25 to 70 mph (40 to 112 km/h). Test speed is normally 50 mph (80 km/h).

This chapter describes the profiler equipment, essential operational details of the profiling system, and critical maintenance activities.

## *2.1 EQUIPMENT*

### 2.1.1 COMPUTER SYSTEM

The profiler's computer and data acquisition electronics are contained in a ruggedized chassis positioned between the front seats of the profiler truck. The profiler sensors interconnect on the back side of the computer chassis. A power switch on the front side of the computer chassis switches on the computer and supplies power to all of the associated electronics. The computer chassis includes internally mounted hard disk and Zip disk drives. Additionally, a monitor, keyboard, printer, and sixteen-key eventboard connect to the computer system. An inverter converts the 12 volt DC power (alternator and batteries) to 110 volts AC to power the computer system.

### 2.1.2 COMPUTER SOFTWARE

The computer software necessary for operations are:

- MS DOS 6.22 (or higher) Operating System,
- ICC MDR Data Collection Software, and
- ICC Profile Data Reporting Software (RP090.EXE).

The DOS operating system is installed on the hard disk drive and is necessary for booting and operating the profiler computer. The AUTOEXEC.BAT and CONFIG.SYS files contain critical parameters for proper operation of the profiler computer. Appendix A contains copies of the necessary AUTOEXEC.BAT and CONFIG.SYS files. If it is necessary to reload the DOS operation system on the profiler computer, please refer to Appendix A to update the installed AUTOEXEC.BAT and CONFIG.SYS files to assure proper operation of the profiler.

The DOS commands DATE and TIME should be added to the AUTOEXEC.BAT file so when the profile computer is booted the operator will have the opportunity to review the computer clock and make any necessary adjustments each time the computer is booted.

The ICC MDR data collection and reporting software are contained in the directory C:\MDRSW\. The current data collection software (MD090LLW.EXE, Version 2.48, 07/25/2000) is launched by the batch file M.BAT. Appendix A contains a copy of the M.BAT file. The MTIRI.BAT and MTBUMP.BAT are batch files that configure parameters for the ICC reporting software (RP090L.EXE) to greatly simplify the creation of the profile reports. Appendix A also contains copies of the MTIRI.BAT and MTBUMP.BAT files.

At least two (2) copies of the ICC MDR data collection and reporting software (i.e., entire C:\MDRSW\ directory) should be made. One copy should be stored with the profiler and one kept at the MDT district office in case problems occur with the software installed on the computer. Diskettes should always be stored in a safe, clean area and away from direct sunlight or rain. Refer to the diskette manufacturer guide for additional instructions.

If any of these software are re-installed, the operator should go through the setup menus described in Section 2.3 of this manual to make sure that appropriate parameters have been set to the correct values.

### 2.1.3 LASER HEIGHT SENSORS

Laser height sensors measure vertical displacement between the vehicle and the road. The profiler is equipped with two Selcom laser sensors securely attached to a sensor bar mounted to the front frame rails of the truck.

Laterally, the laser sensors are located in the center of each wheel path and should be at a distance of 34 inches (864 mm) from the center of the vehicle. This sensor setup results in a spacing of 68 inches (1,727 mm) between left and right sensors. The sensor bar is not designed to support the weight of the operator or other persons. Do not sit or stand on the sensor bar at any time.

The two laser sensors are equipped with removable covers. The covers should be in-place when testing is not being performed to protect the sensors. The covers are removed when performing sensor checks and while collecting profile data.

Each laser sensor consists of a laser head unit mounted to the sensor bar connected by cable to a matched processing unit mounted inside the truck. If a laser head is connected to a non-matching processing unit, the laser will be damaged.

The switch for turning the lasers 'On' and 'Off' is located on the front panel of the computer chassis adjacent to the drivers seat (Figure 2-1). The computer system must be powered on in order for the laser to be turned on. Depending on ambient lighting conditions (and whether or not the laser sensor has additional colored diode), the laser spot may not be visible on the ground. The operation of the lasers can be verified using the procedures described in Section 3.1.

The laser height sensors in the profiler can malfunction at elevated temperatures. At approximately 50°C (122°F) the laser sensors will begin to produce errors and at approximately 60°C (140°F) the laser sensors will turn off to prevent damage.

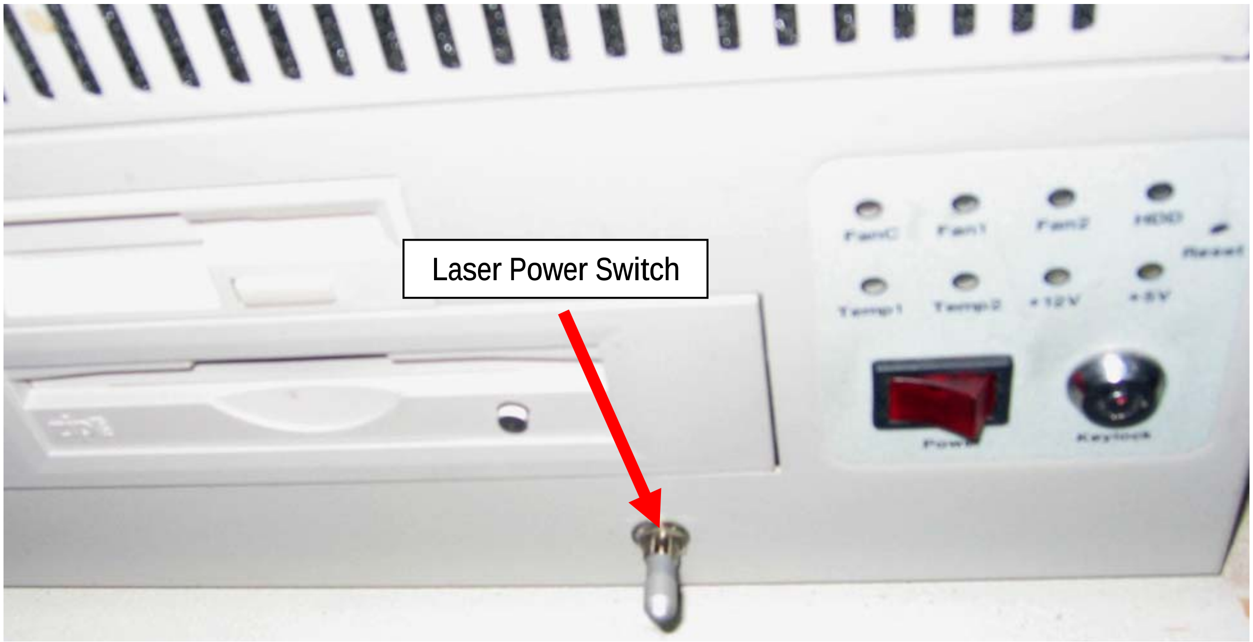


*Figure 2-1. Laser Power Switch Location.*

Before performing any profile data collection or calibration activities, the laser sensor lenses should be inspected and cleaned (if necessary). Always make sure that lasers are turned off when inspecting the sensor glass, cleaning the sensors or when performing maintenance on the sensors.

To clean the laser sensor lenses, the following procedure should be followed to prevent damage to the laser sensor lens:

1. Flood the lens surface with clean water or liquid glass cleaner solution.
2. Gently scrub the wet lens surface using a clean soft cloth or paper towel.
3. Wipe lens surface dry in one stroke using a clean and dry soft cloth or paper towel.

Extreme caution should be taken when cleaning the laser lens surfaces. Avoid using any cloths or cleaners that could potentially scratch the lenses. Also, avoid any gritty contaminants being rubbed against the lenses.

Additionally, operators should be warned not to let the laser beam strike their eyes. This laser is powerful enough to damage eyesight. Furthermore, the reflection of the laser beam from a surface such as a polished plate, a calibration bar or a watch may also damage eyesight. Operators should take all necessary steps to avoid a reflected laser beam coming into contact with the eye.

### 2.1.4 Accelerometers

The accelerometers are used in the profiler to account for the motion of the vehicle during profiling. Two accelerometers are attached to the sensor mounting bar with one located directly above each laser sensor. The accelerometers essentially determine how much the laser sensors move during profile data collection.

The accelerometers do not require special maintenance or handling. The pre-run accelerometer calibration check described in Section 3.2 should be performed to verify proper operation of the accelerometers. If an accelerometer needs replacement, the computer system should be completely powered off before detaching the accelerometer cable from the computer.

### 2.1.5 Distance Measuring Instrument (DMI)

The distance measuring instrument (DMI) is a system that determines how fast the profiler is moving and how far it has traveled. The DMI takes a pulse signal from the profiler's speed sensor to compute the speed and distance traveled.

Tires are a critical component of the DMI. Proper maintenance of the tires is covered under MDT maintenance policies. In most instances, the tires should be inflated following the guidelines of the truck and tire manufacturer documentation.

The tires should be sufficiently warmed up prior to testing a pavement section. The tires should be considered warmed up sufficiently if the profiler has traveled about 5 mi (8 km) at highway speeds after being parked. However, the distance for warming up tires may need to be changed depending on local weather conditions.

Warming up the tires will cause a slight increase in tire pressure versus the cold tire pressure. The DMI is affected by the tire pressure of the rear tires. The operator should note the rear tire pressures when the DMI of the profiler was last calibrated. The tire pressure of the rear tires of the vehicle for all data collection runs should be within ± 2 psi (13.78 kPa) of the tire pressure that was recorded when the DMI was last calibrated. Before performing data collection, the operator should adjust the tire pressure of the rear tires to ensure that the tire pressure is within this specified limit. The same tire pressure gauge should be used to measure tire pressure during both calibration and testing.

### 2.1.6 Photocell

The profiler is equipped with a photocell mounted on the sensor bar. It can be rotated around a horizontal axis. The photocell is used to create a reference reset when triggered by a reflective surface. The location where it is triggered is then stored in the event file. The positioning of the photocell is shown in Figure 2-2.

*Figure 2-2. Photocell Mounted on Sensor Bar.*

The photocell has some limitations to its working range (e.g., distance and reflectivity). The photocell can be positioned to sense reflections from pre-placed marks on the road surface and sense reflective markings on pre-placed cones along the roadside.

Reflective tapes can be placed on the road surface to trigger the photocell. However, these tapes can be expensive and may have the tendency to not stick to the road surface.

Cones should be placed on the shoulder of the road in a position to avoid being hit by traffic or blown over by vehicle generated turbulence. Additionally, the photocell should be rotated around its pivot to align its beam with the reflective material on the cone. The operator should consider the photocell /cone alignment and compensate to avoid false triggering of the photocell by existing reflective markers and surfaces along the road being profiled.

Some trial and error should be expected to get the cones and photocell positioned for error free operation at some projects. The operator should also be aware that at certain times of day low sun angles have the potential of interfering with the photocell and causing either false triggers or non-triggers.

Before performing any data collection, the photocell lens should be inspected and cleaned if necessary. To clean the photocell lens, the following procedure should be followed to prevent damage to the lens:

1. Flood the lens surface with clean water or liquid glass cleaner solution.

2. Gently scrub the wet lens surface using a clean soft cloth or paper towel.
3. Wipe lens surface dry in one stroke using a clean and dry soft cloth or paper towel.

Extreme caution should be taken when cleaning the photocell lens. Avoid using any cloths or cleaners that could potentially scratch the lens. Also, avoid any gritty contaminants being rubbed against the lens.

#### 2.1.7 Equipment Maintenance & Repair

Decisions required for proper maintenance and repair should be based on the testing schedule and expedited as necessary to prevent disruption of testing. Maintenance activities on the profiler should be performed prior to mobilization for testing. Operators should be familiar with specific, detailed MDT maintenance requirements for the profiler.

### *2.2 POWER-UP, BOOTING AND SHUTDOWN PROCEDURES*

#### 2.2.1 Power Sources

There are two batteries in the profiler, one located under the hood of the vehicle, and one located in the truck bed in the forward left corner. The rear battery supplies power to the computer and the electronic equipment in the profiler through an inverter. The computer and the electronic equipment in the profiler can also be powered through an external AC power source (house power) by connecting a battery charger to the rear battery. Both batteries in the profiler are charged when the vehicle engine is running.

During data collection, power will be supplied through the inverter. When the engine is turned off (e.g., while performing calibration checks, troubleshooting, or operating the computer when parked in the shop), an external battery charger should be used to supply power.

#### 2.2.2 Power Switch Location

The primary power switch for powering the profiling system is located on the front panel of computer chassis located between the front seats as indicated in Figure 2-3. This switch in the ‘On’ position will power the computer system with or without the vehicle engine running; however, leaving the switch in the ‘On’ position with the engine turned off will cause the batteries to discharge completely.

The laser power switch is located next to the main computer power switch on the front of the computer chassis. The main power switch must be in the ‘On’ position in order for the lasers to be powered. It is recommended that the computer system be fully booted with the MDR software running before the laser power is switched on.

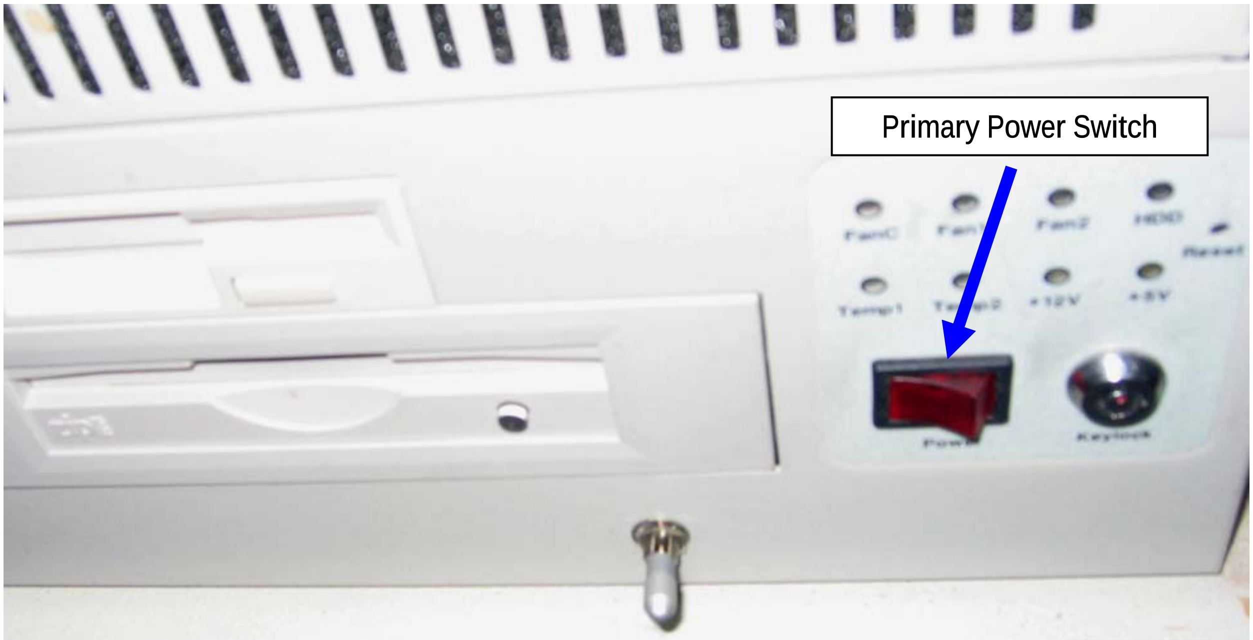

*Figure 2-3. Primary Power Switch Location.*

### 2.2.3 Profiler Power Supply

The profiling computer and equipment can be powered in two ways. While the engine is running, the alternator provides enough power to keep both batteries sufficiently charged to provide the inverter the necessary voltage to run the computer and profiling electronics. Otherwise, the battery charger (plugged into a standard wall outlet) can be connected to the rear battery to power the computer and profiling electronics when the engine is turned off.

While the computer is running, it is imperative that the batteries have sufficient charging either with the engine running or the battery charger connected. If the inverter is unable to draw enough voltage from the batteries, it will stop producing the AC voltage that operates the computer and the computer will power down. Sudden power loss to the computer could cause damage to delicate internal components.

### 2.2.4 Computer Booting Procedure

The following procedure should be followed when starting the computer and profiling systems. Before powering the computer, there should be an adequate supply of power to the inverter. Either the engine should be running or the battery charger should be connected to the rear battery.

1. Remove covers from laser lenses and inspect laser lenses (clean if necessary).
2. Switch the main power switch to the 'On' position.
3. Allow the computer to boot up.
4. Check the system date and time and adjust if necessary.
5. At the C:\ prompt, type 'M' and then press the Enter key to launch the MDR data collection program.

6. The main menu of the MDR program will show on the computer monitor (Figure 2-4).
7. Switch the laser power switch to the 'On' position.

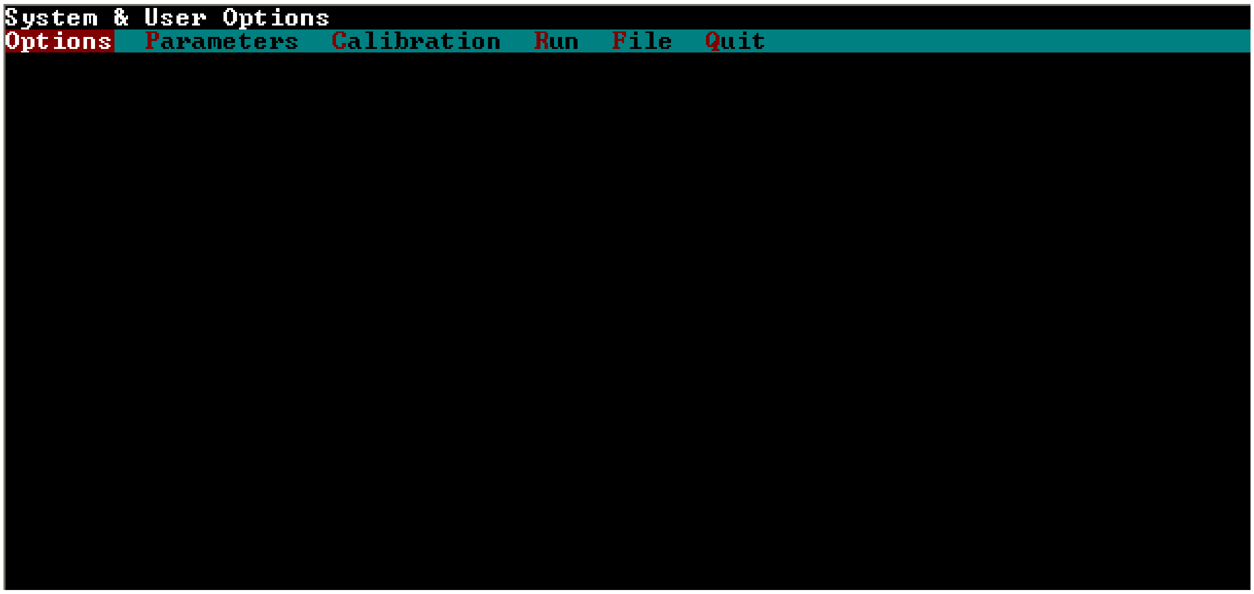


*Figure 2-4. MDR Software Main Menu.*

### 2.2.5 SHUTDOWN PROCEDURE

The following procedure should be followed when turning off the computer and profiling systems:

1. Remove any Zip disks remaining in the Zip drive.
2. Switch the laser power switch to the 'Off' position.
3. If the MDR program is running, select Quit from the Main Menu, and then enter 'Y' to confirm the quit request. The C:\ prompt will then be displayed on the screen.
4. Switch the main power switch to the 'Off' position. The power to the computer has now been turned off.
5. For shutting down when powered by house power, disconnect the battery charger from the profiler's battery.
6. Re-cover the laser sensors.

## *2.3 SOFTWARE SETUP*

The MDR software, MD090LLW.EXE, is started with the M.BAT batch file. It is used to collect and save the profile data. The reporting software, RP090L.EXE, is used for bump and IRI (International Roughness Index) report generation. Settings in the MDR program and reporting program that need to be verified and/or updated are presented in the following sections.

The settings in the MDR software should be checked to ensure that they are set with the correct values. These settings should be checked if the software is re-installed or if problems are encountered. There are some settings that the operator will have to set or update once the software is installed.

The following steps take the operator through the different settings that need to be checked and/or updated.

1. Launch the MDR software by entering 'M' at the command prompt.
2. MDR main menu should now be displayed on the screen.
3. Options Menu Settings:

   In the MDR main menu, select 'Options'. The drop down menu shown in Figure 2-5 will be displayed on the monitor.

   The Reference Post Display Mode should be set to 'Mile' or 'Meter' and the Output File Size should be set to 'Hard Disk'. The User should show 'MTDOT_LW' and Version should correspond to the current version. If either of these two fields is different, ICC should be contacted.

   Please note in Figure 2-5, if the available memory shows '0 Pgs', the system will not collect and store data.

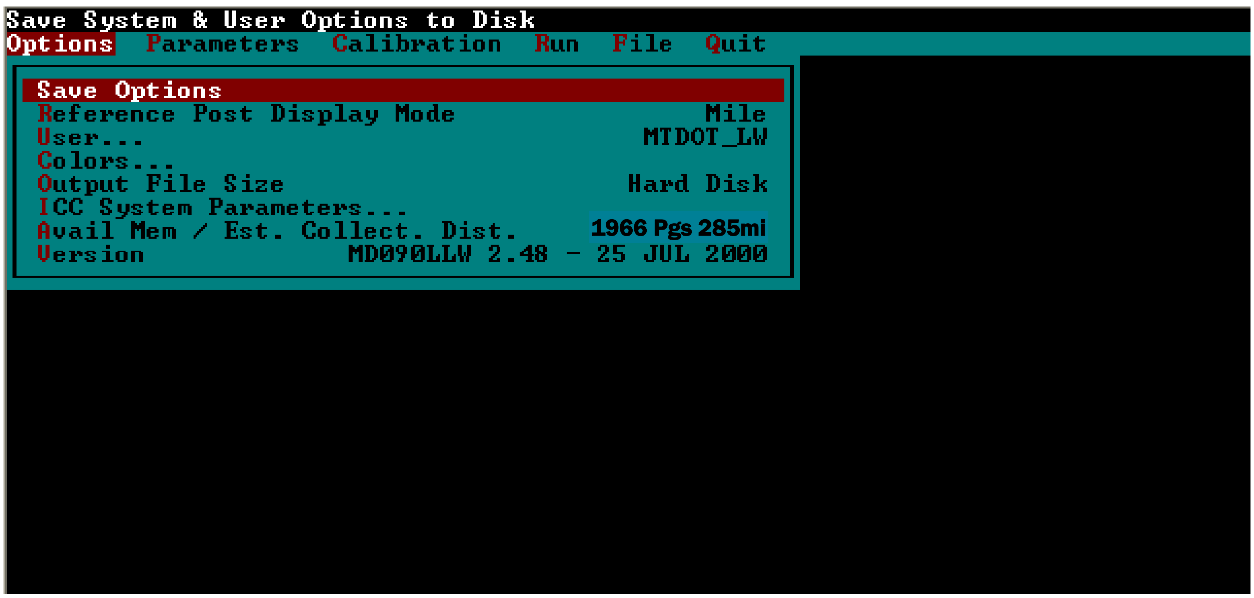


*Figure 2-5. MDR Software Options Menu.*

4. ICC System Parameters Menu Settings:

   In the Options Menu, highlight 'ICC System Parameters' and press Enter key. The parameters should match the values shown in Figure 2-6. Additional parameters are set in the 'morE' submenu and should match the values shown in Figure 2-7. The parameter settings should match the following values and if any of the parameters shown are different, check with ICC.

‘ICC System Parameters…’ Submenu

| | | | | | |
|---|---|---|---|---|---|
| Ref Sen Pos | | 6 | | | |
| DAS-80 Mode | | SINGLE | | | |
| Profile Sensors | | 1 | 2 | | |
| Faulting Sensors | | 0 | 0 | | |
| send GPS Init Msgs | | Off | | | |
| com2 Mode | | On | | | |
| 1 Com1 Port Setup | | 9600 | FA | Com1 | On |
| 2 Com2 Port Setup | | 9600 | FA | Com2 | On |
| 3 GPS Port Setup | | 4800 | 83 | Aux1 | Off |
| 4 Video Port Setup | | 19.2 | 9B | Aux2 | Off |
| 5 LCD Port Setup | | 9600 | 9F | Com1 | Off |
| 6 Cmd Port Setup | | 115K | 83 | Com2 | Off |
| 7 Las5200 Port Setup | | 38.4 | 83 | Aux1 | Off |
| 8 Image1 Port Setup | | 9600 | 83 | Aux4 | Off |
| 9 Image2 Port Setup | | 9600 | 83 | Aux4 | Off |
| A Image3 Port Setup | | 9600 | 83 | Aux4 | Off |
| Target… | 1-F2 | 2-F9 | 3-F9 | 4-F9 | 5-F9 |

‘morE…’ Submenu

| | | |
|---|---|---|
| Laser1 Address | 280 | |
| Laser 2 Address | 282 | |
| Laser 3 Address | 284 | |
| Laser 4 Address | 286 | |
| Laser 5 Address | 288 | |
| C – Select 1ms Accelerometer Rate | | Off |
| X-distance to GPS antenna | 0.0 | |
| Y-distance to GPS antenna | 0.0 | |
| Z-distance to GPS antenna | 0.0 | |
| MDR Prog Files Dir | C:\MDRSW\ | |
| Report List | C:\MDRSW\MDRRPT.LS | |

After the parameter settings have been checked, press Escape key twice to get back to the MDR main menu.

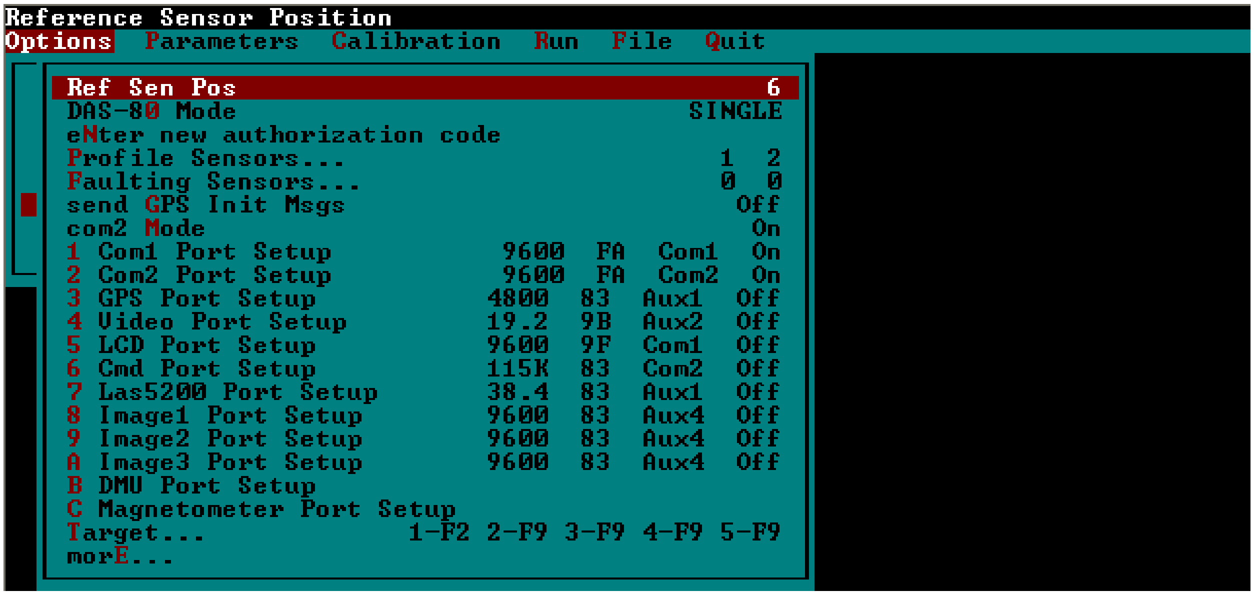


*Figure 2-6. MDR Software ICC System Parameters Menu.*

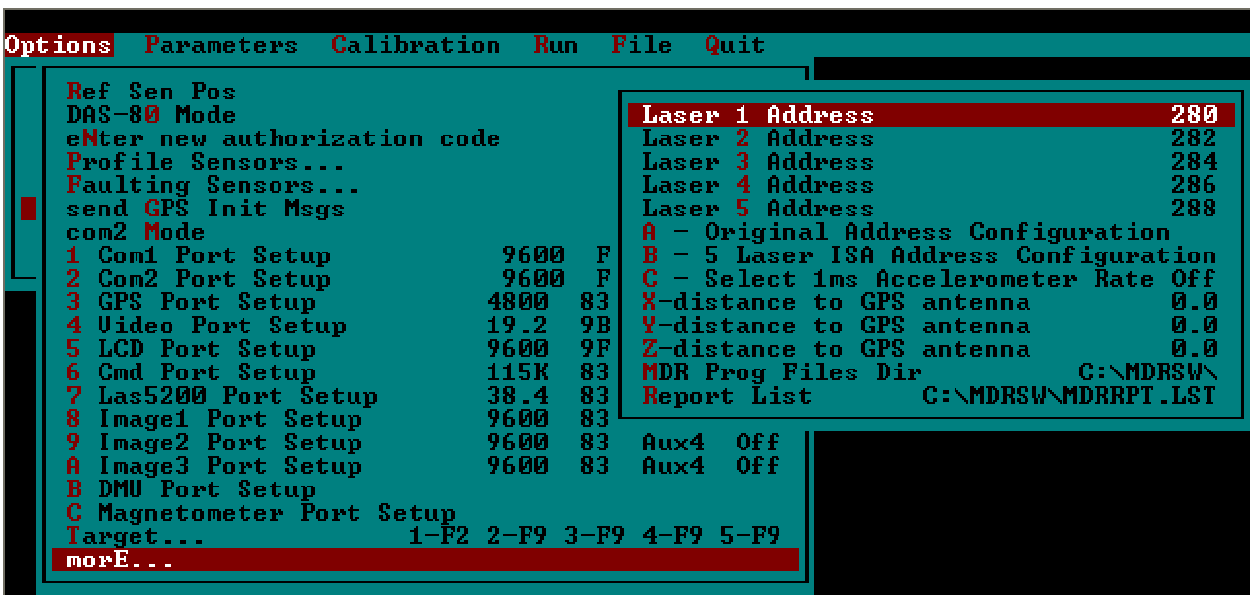


*Figure 2-7. MDR Software More ICC System Parameters Menu.*

5. Parameters Menu Settings:

   The 'Operator' and 'Driver' entries should be set for the names of the operator and driver using first initial and last name for each individual. As shown in Figure 2-8, the 'Vehicle' should be set to the appropriate MDT vehicle number for the profiler: 07-121X, where X is the appropriate district number (e.g., 1 for Missoula, 2 for Butte, etc.).

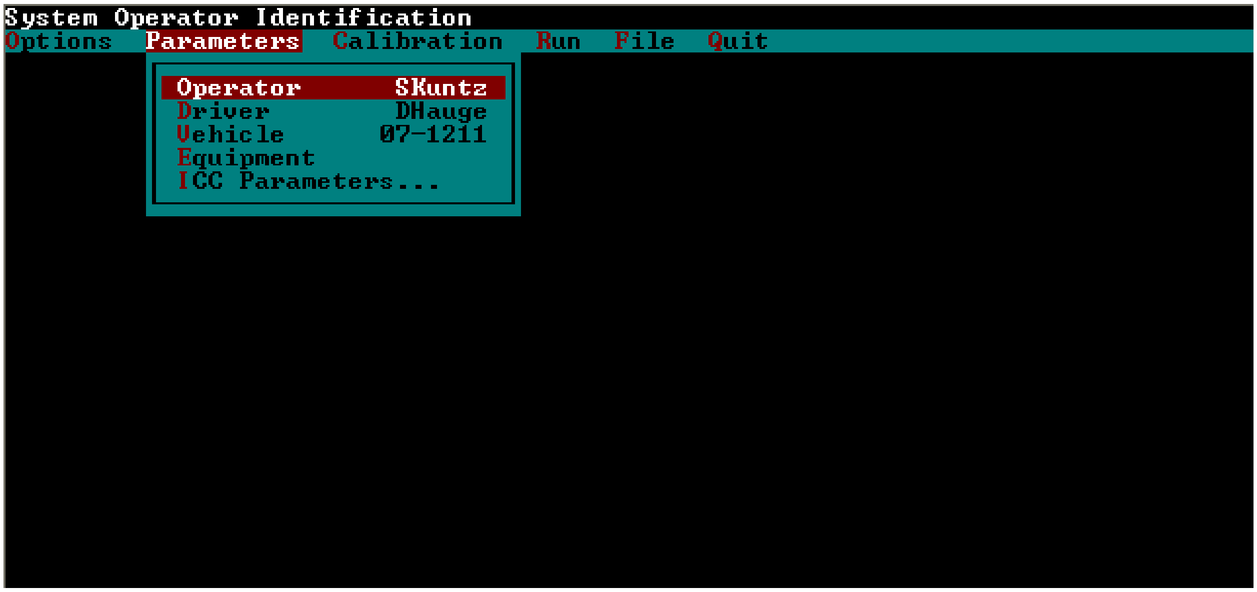


*Figure 2-8. MDR Software Parameters Menu.*

6. Sensor Configuration Menu Settings:

   In the MDR main menu select ‘Calibration’ and the drop down menu shown in Figure 2-9 will be displayed. Highlight ‘Sensors…’ in this menu, and press Enter key. The Sensor Calibration menu shown in Figure 2-10 will be displayed on the monitor.

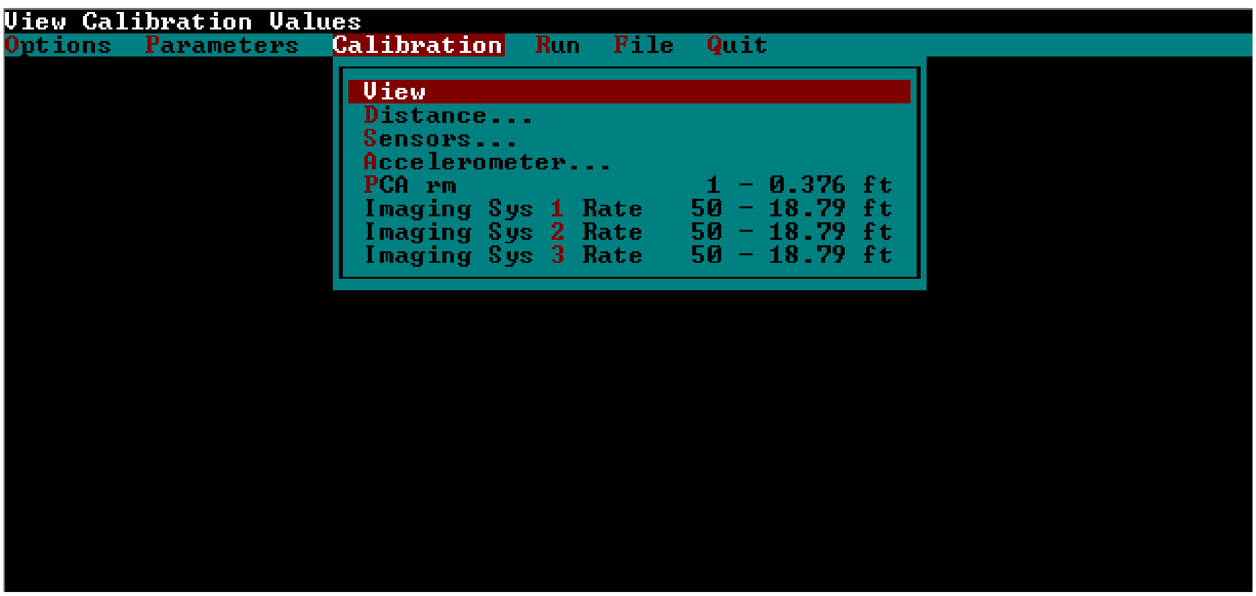


*Figure 2-9. MDR Software Calibration Menu.*

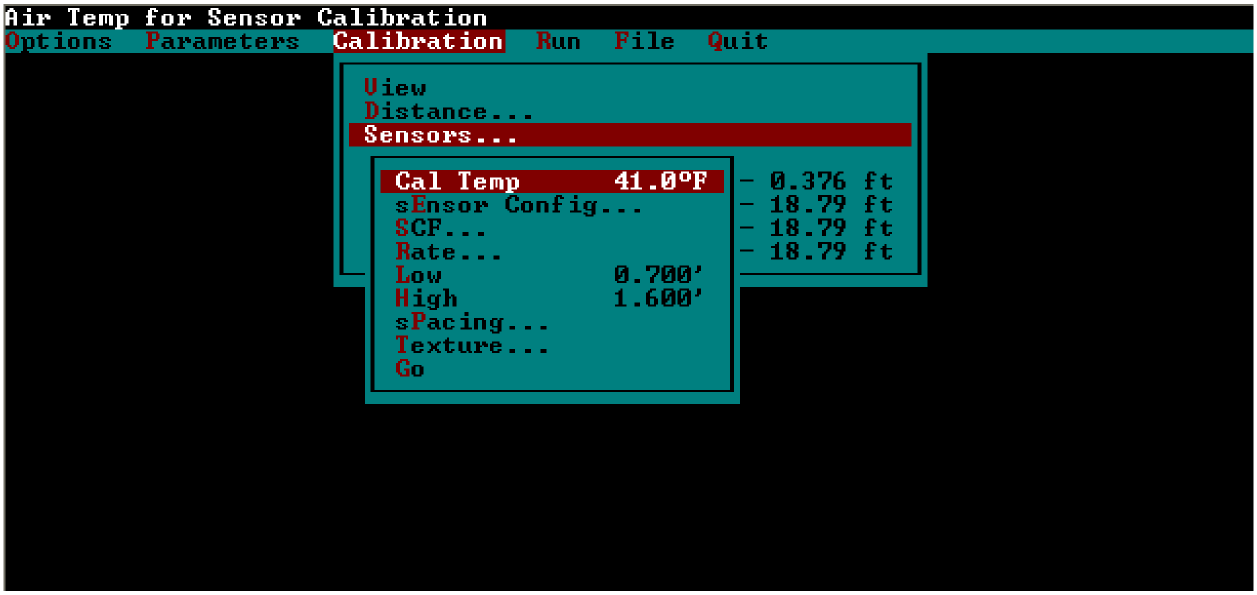


*Figure 2-10. MDR Sensor Calibration Menu.*

In Sensor Calibration Menu, highlight 'sEnsor Config…' and press the Enter key. The sensor configurations will be displayed on the monitor as shown in Figure 2-11. Parameter settings shown on the monitor should match the values shown below:

'sEnsor Config…' Submenu

| | |
|---|---|
| Height Sensor(s) | 2 of 2 |
| 1 – Pos 1 – Lt Wheel Path | Selcom200 |
| 2 – Pos 2 – Rt Wheel Path | Selcom200 |
| 3 – Pos 3 – Sensor | None |
| 4 – Pos 4 – Sensor | None |
| 5 – Pos 5 – Sensor | None |
| 6 – Pos 6 – Sensor | None |
| 7 – Pos 7 – Sensor | None |
| 8 – Pos 8 – Sensor | None |
| 9 – Pos 9 – Sensor | None |
| A – Pos 10 – Sensor | None |
| B – Pos 11 – Sensor | None |
| C – Pos 12 – Sensor | None |
| D – Pos 13 – Sensor | None |
| E – Pos 14 – Sensor | None |
| F – Pos 15 – Sensor | None |

If the parameters shown are different, check with ICC and set parameters to appropriate values. After checking the parameters, press the Escape key to return to the Sensor Calibration Menu.

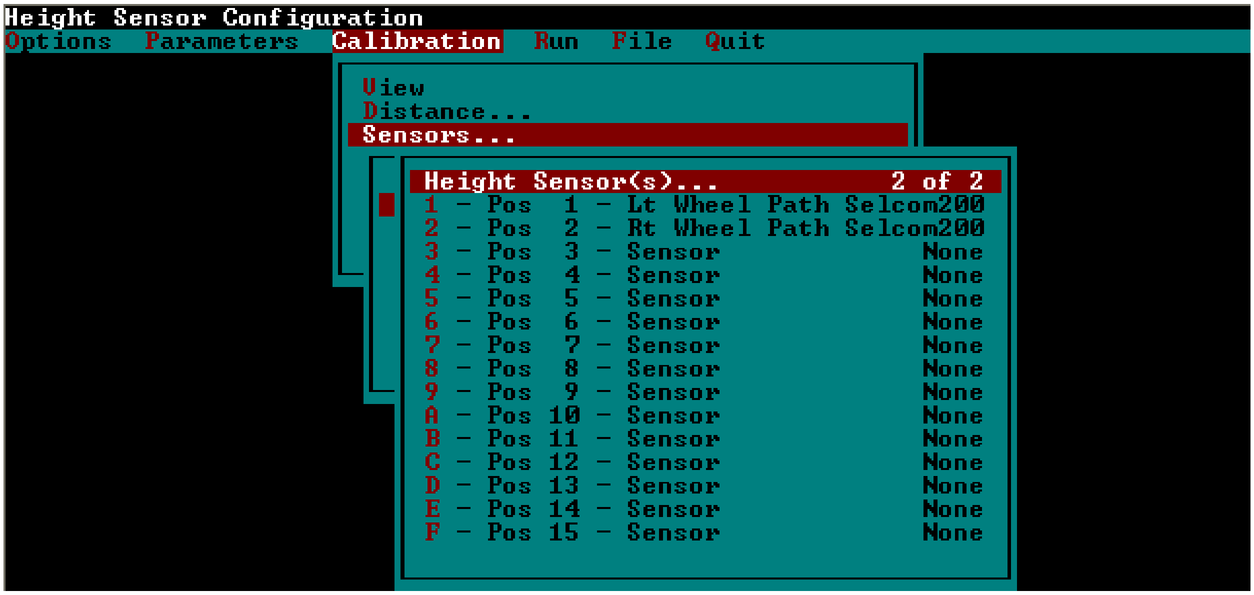

*Figure 2-11. MDR Software Sensor Configuration Settings.*

7. Sensor Rate Settings:

   In the 'Rate…' submenu of the Sensor Calibration Menu, the Profile Rate should be set at value 1 (0.376 ft), the Rutting Rate should be set at value 1 (21 MPH), and the Ser5200 Rate should be set at value 1 (0.376 ft) as shown in Figure 2-12. The Profile Rate should be set at value 1 (0.115 m), the Rutting Rate should be set at value 1 (34 KPH), and the Ser5200 Rate should be set at value 1 (0.115 m) when the Reference Post Display Mode is set to 'Meter' in step 3 for projects with metric stationing.

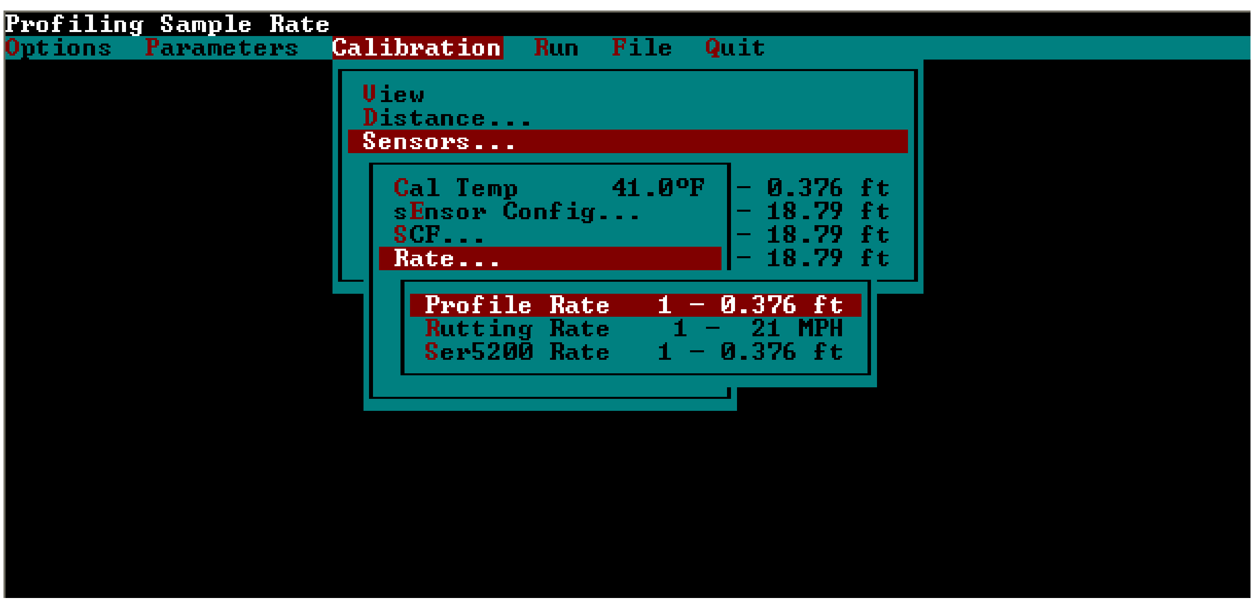

*Figure 2-12. MDR Software Sensor Rate Settings.*

8. Sensor Spacing Settings:

In the 'sPacing…' submenu of the Sensor Calibration Menu, the values should be set to the following values as shown in Figure 2-13.

'sPacing…' Submenu

| | | |
|---|---|---|
| 1 – Spacing | 1 - 1 | 0.000" |
| 2 – Spacing | 1 – 2 | 68.000" |

If any of the parameters are different, set parameters to the indicated values by highlighting parameter, pressing Enter, entering correct value in window that opens, and pressing Enter key again to close window. After checking the parameters, press the Escape key twice, to get back to the Calibration Menu.

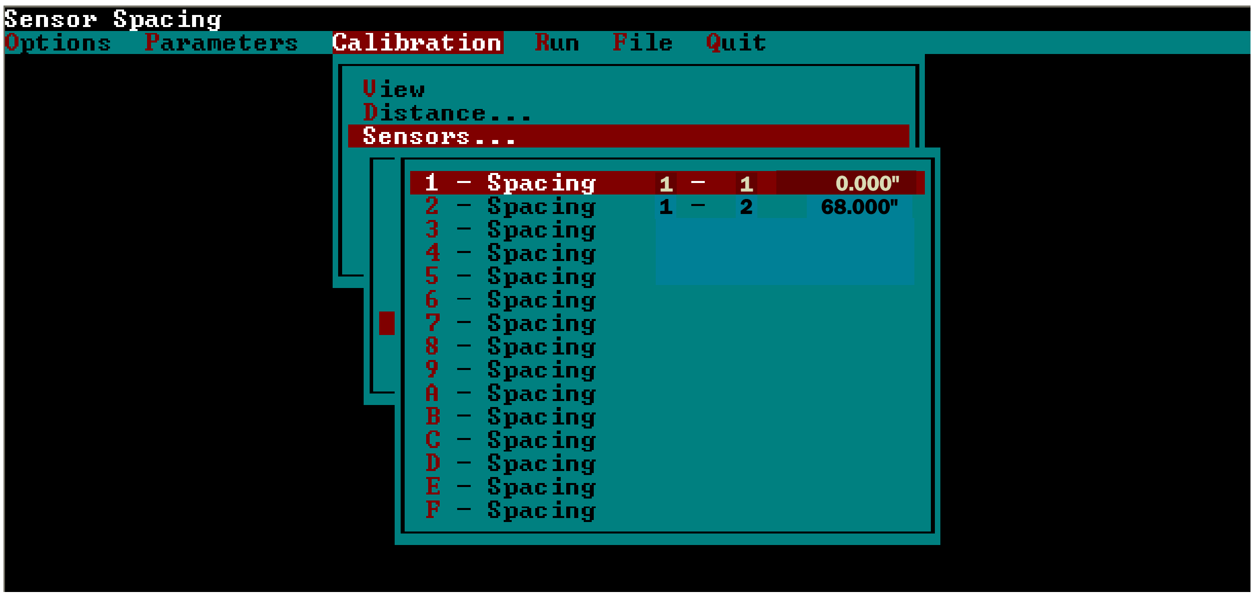


*Figure 2-13. MDR Software Sensor Spacing Settings.*

9. Accelerometer Calibration Menu:

From the 'Accelerometer…' menu, the HPF value should be set to 0.020 as shown in Figure 2-14. In the 'FGF…' submenu, the 1st and 2nd FGF values should be set to 1.00 as shown in Figure 2-15. Please note that accelerometer line on top of menu should read "2 of 2".

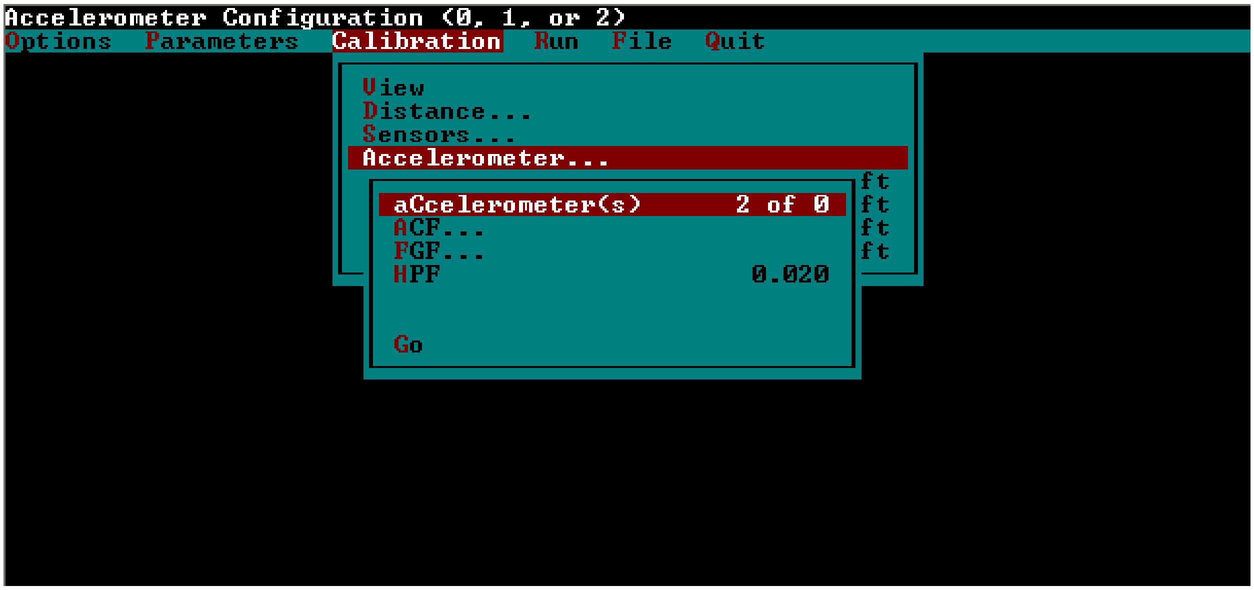


*Figure 2-14. MDR Software Accelerometer Calibration Menu.*

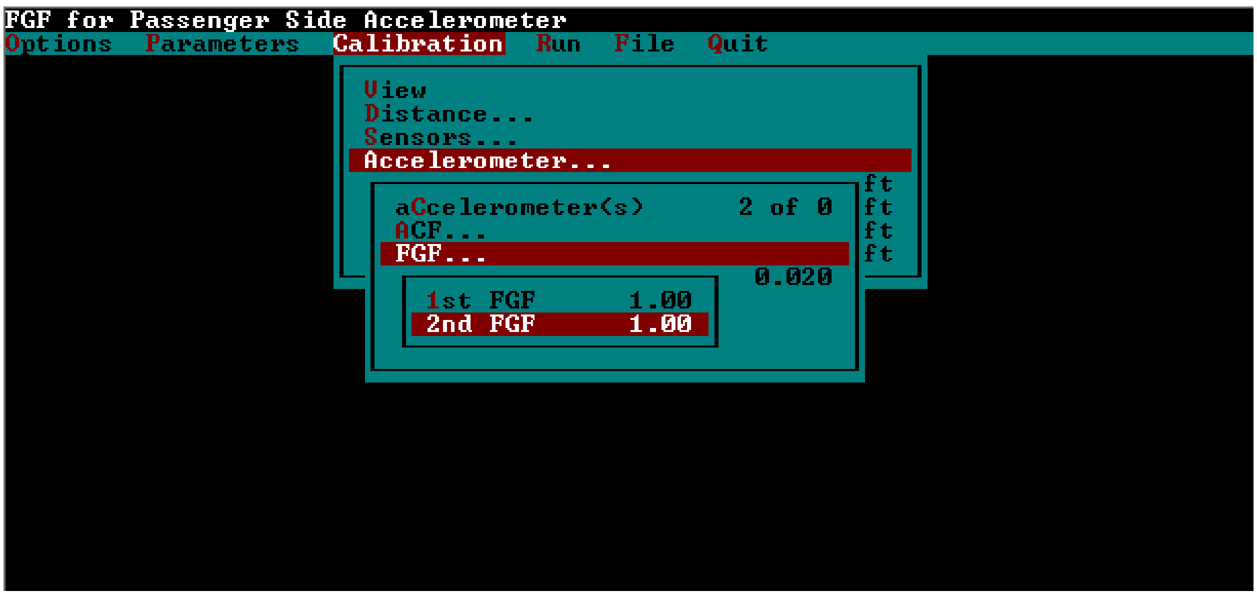


*Figure 2-15. MDR Software Filter Gain Factor (FGF) Settings.*

10. Run Menu Settings:

    In the MDR Main Menu, select 'Run' and the Run Menu shown in Figure 2-16 will be displayed on the monitor.

    County should be set to the county where the project is located, spelled out in all capital letters (e.g., MISSOULA). Route should be set to the highway or road designation for the road where the project is located, spelled out in all capital letters using a description that will not cause confusion with similarly numbered roads (i.e., INTERSTATE 90, STATE ROUTE 200, etc.). Direction should be toggled by selecting the first letter of the direction for the lane being profiled (i.e., E for East, W for West, N for North, or S for South). Asc/Dsc Ref Point should be set to '+' for normal profiling operations. Lane should be set for the lane being profiled, spelled out in all capital letters (i.e., DRIVING, PASSING, or TURNING). Start Ref and End Ref can be used by the profiler operator to designate the project stationing values. Line 7 is a general comment field that lists the EPM and contractor who witness the profiling activities.

*Figure 2-16. MDR Software Run Menu.*

11. Run Options Menu Settings:

    In the MDR Run Menu, highlight 'Options…' and press the Enter key. The Run Options Menu shown in Figure 2-17 will be displayed on the monitor.

*Figure 2-17. MDR Software Run Options Menu.*

The values for the parameters shown on the monitor should match the following:

| | | | | |
|---|---|---|---|---|
| DMI Simulator | | Off | | |
| User Mode | | SINGLE | | |
| Mays | | Off | | |
| Profile | | On | | |
| GPS… | | Aux1 Off | | |
| lcd Display… | | Com1 Off | 1 | |
| speed Collect | | On | | |
| speed Limit | | ±1.0 | | |
| secTion incr… | | Off | | |
| target… | | Com1 On/Com2 | | Off |
| tracKing | | Off | | |
| cOmmand mode | | Com2 Off | | |
| Imaging… | 1-Aux4 Off | 2-Aux4 Off | 3-Aux4 Off | |
| iRi… | | On | | |
| las5200 com port | | Aux1 Off | | |
| 3 Remote SLD | | Off | | |

The DMI Simulator is used strictly to demonstrate the equipment is working properly. This is not an option that should be on when collecting data. This option simulates DMI pulses and allows the RUN functions to be demonstrated without moving the profiler. Trying to collect data with the simulator on will result in extremely high speed and distance readings. This error results from the system receiving distance pulses from two sources. If the profiler is not moving but showing a speed in the RUN screen, most likely the simulator is on and must be turned off.

12. IRI Settings Menu:

From the Run Options Menu, select 'iRi…' and the IRI settings shown in Figure 2-18 will be displayed on the monitor. The IRI settings should be adjusted to match the following list:

| 'iRi…' Submenu | |
|---|---|
| Mode | On |
| HCS/avg IRI | Avg |
| iri Scale | 63360 |
| Negative rut | On |
| Filter | On |
| Wavelength | 300.0 |
| Moving Average | 1 |
| section Control | Off |
| interval Control | On |
| Interval | 0.1 |
| interval Reset | Off |
| speed Limit | 15.0 |
| ride Number | Off |

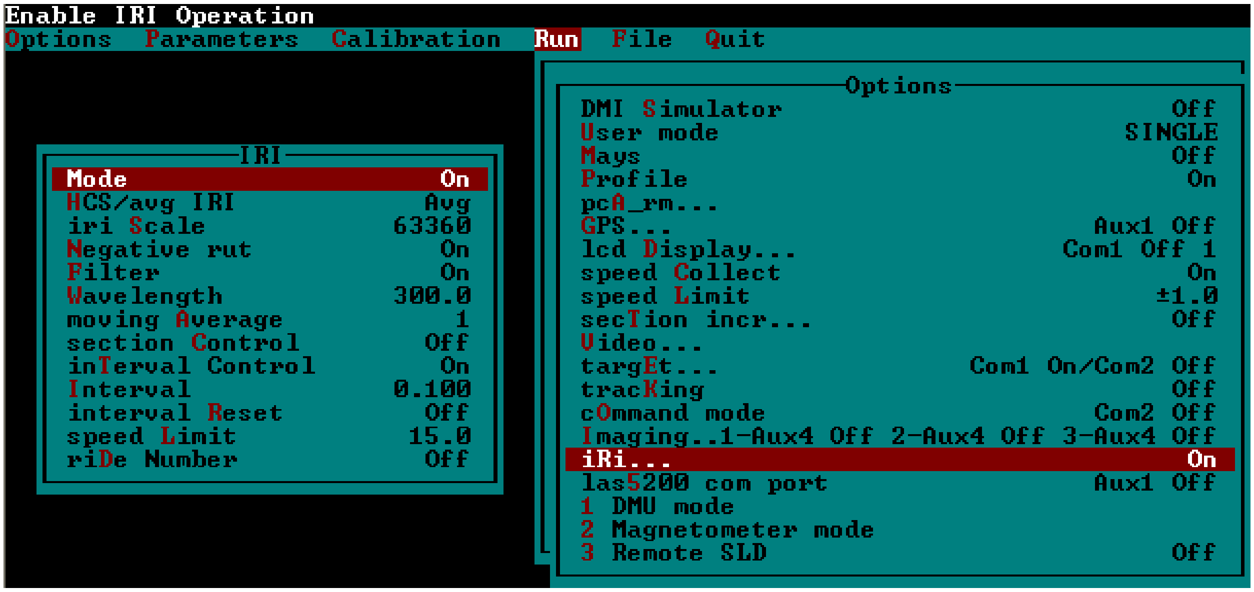

*Figure 2-18. MDR Software IRI Options Settings.*

## 3.0 CALIBRATION OF EQUIPMENT

Calibration is used to establish and adjust the transducer operating characteristics of the MDR system. There are three types of transducers in the system: linear distance measuring system (i.e., DMI), the vertical height sensor (i.e., laser sensor), and the vertical position accelerometer. The following sections describe the calibration and checks of these components.

A comprehensive calibration and sensor check will be performed at an interval of thirty (30) days, during construction season. There are four components to the calibration and sensor check procedure described in this chapter. The four components in the order that they should be performed are: 1) full calibration check of laser sensors, 2) calibration of accelerometers, 3) bounce test profiling system verification, and 4) calibration of DMI.

### *3.1 FULL CALIBRATION CHECK OF LASER SENSORS*

The laser sensors are calibrated and sealed by the manufacturer. The operator cannot calibrate these sensors; however, the lasers can be checked. A comprehensive check of laser sensors should be performed at an interval of thirty (30) days during construction season, which will check the accuracy of the laser sensors over a 1 inch (25.4 mm) measuring range. This check is referred to as the Full Calibration Check of laser sensors and is different from the Pre-Run Check described in Chapter 4. A full calibration check of the laser sensors must also be performed whenever laser sensors problems are suspected or when a sensor is repaired or replaced.

Power to the electronic equipment should be turned on for about 15 minutes prior to performing any calibration or calibration checks so that the electronic equipment is allowed to warm up and stabilize.

The results of the full calibration check of the laser sensors will be recorded under the “LASER SENSOR CALIBRATION CHECK” section on the MDT Profiler Calibration Record Sheet (Appendix B) and kept in the profiler log book.

Once a year, before the beginning of the construction season, each calibration block's thickness will be measured using micrometers. Each block's thickness with the value converted to feet is recorded in the "Actual Block Thickness" line of the Profiler Calibration Record Sheet each time the full calibration check is performed.

The full calibration check of laser sensors should be performed in an enclosed building with a level concrete floor using external power (house power) to power the profiler system. If the full calibration check is performed in the field, the location where the check is performed should protect profiler from wind and other vibrations. The pavement surface should be as level as possible and lighting conditions should be consistent from sensor to sensor (i.e., face profiler away from the sun). An external power source should be used, whenever possible.

The following procedures should be used to set up the profiler to perform the full sensor calibration check.

1. Check Sensor Height: Make sure the laser sensors are powered off. Remove sensor covers. Measure distance from floor to glass face of the laser sensor. This distance should within 13 in ± 0.5 in (330 mm ± 10 mm). The distance from ground to face of the sensor should not change between calibration checks that are performed monthly, unless the sensors have been moved or replaced since the previous calibration check. Adjust the sensor if required so that the height from glass face of sensor to ground is 13 in ± 0.5 in (330 mm ± 10 mm). Record these measurements in the appropriate boxes in the "Lens to Ground Measurement" line under the "LASER SENSOR CALIBRATION CHECK" section on the Profiler Calibration Record Sheet.

2. Clean Sensor Glass: Gently clean each lens following the guidelines described in Chapter 2. When cleaning the lenses, extreme care should be taken to prevent scratching of the lenses. Always make sure that lasers are turned off when inspecting the sensor glass, cleaning the sensors or when performing maintenance on the sensors. Additionally, operators should be warned not to let the laser beam strike their eyes. This laser is powerful enough to damage eyesight. Furthermore, the reflection of the laser beam from a surface such as a polished plate, a calibration bar or a watch may also damage eyesight. Operators should take all necessary steps to avoid a reflected laser beam coming into contact with the eye.

3. Warm Up Electronics: Power the computer system and lasers. Let equipment warm up for at least 15 minutes.

4. The operator should be outside of the profiler when the calibration check is performed. Adjust the computer monitor so that it can be seen from outside the vehicle, and the keyboard should be placed on the seat of the profiler. Do not enter the profiler, bounce or bump the profiler, or lean on the profiler during the calibration check.

5. In the MDR main menu, select 'Calibration' to display the Calibration Menu. Highlight the 'Cal Temp' selection and press Enter key.

6. Enter an accurate air temperature value ± 3°F and press the Enter key.

7. In the Calibration Menu, make sure that all parameters match the settings described in Section 2.3.

8. In the Calibration Sensor Menu, highlight ‘Go’ and press the Enter key. The monitor will display the sensor calibration screen similar to Figure 3-1.

   The items on the screen are as follows:

| | |
|---|---|
| Number of Samples | The number of sensor readings. |
| Sensor | The height sensor position number on the test vehicle (1 for Left and 2 for Right). |
| Count | The count the sensor required for the last height sample. |
| Height | The height of the last sample. |
| Avg. Height | Average height of all samples. |
| Gate/Zero | Number of hardware errors detected. |
| Low | Number of sensor readings that are below the Low limit. |
| High | Number of sensor readings that exceed the High limit. |
| Dif | Number of samples where differences in successive samples are greater than 15 inches (381 mm). |
| Total | Total number of errors detected. |

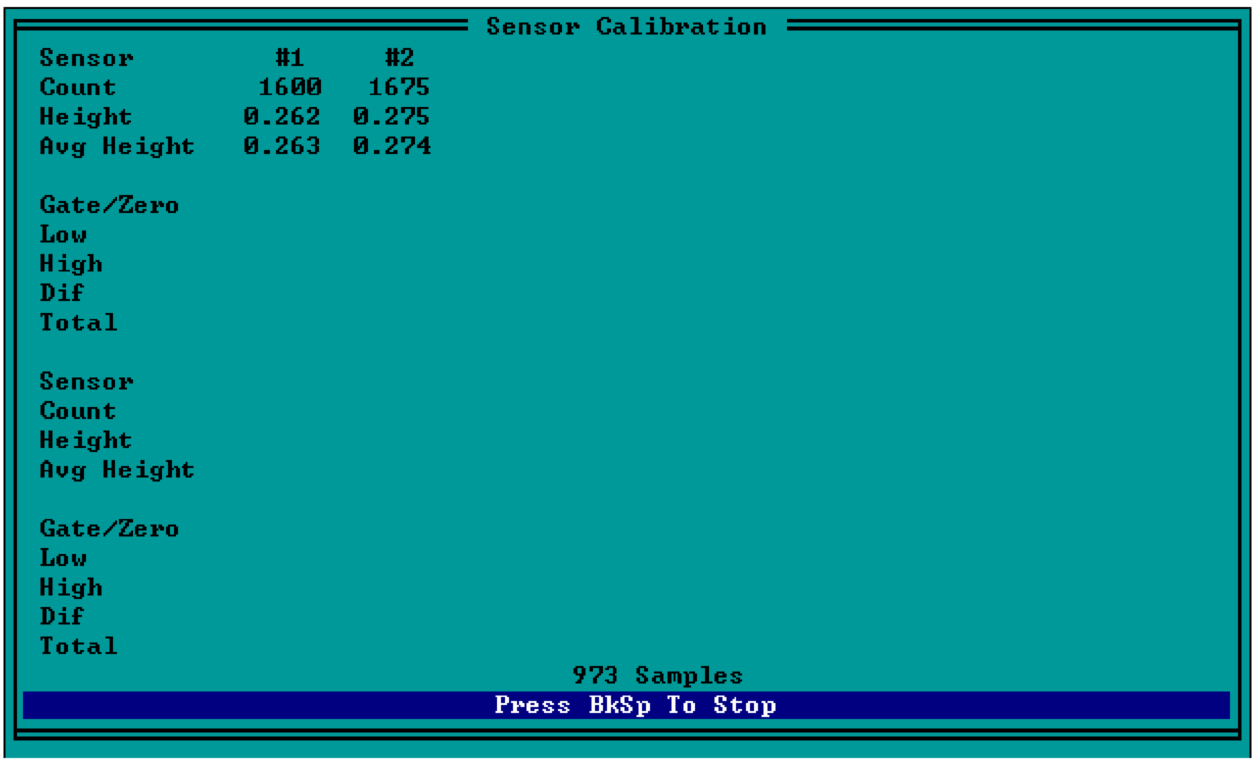

*Figure 3-1. MDR Software Sensor Calibration Screen.*

9. Record the actual ¼”, ½”, and 1” calibration block thicknesses (in feet units) in the appropriate spaces on line 1 (Actual Block Thickness) under the “LASER SENSOR CALIBRATION CHECK” section of the Profiler Calibration Record Sheet.

10. Verify that no blocks, objects, or debris are directly under the laser sensors. Press the Enter key to start reading the laser values. After a minimum of 1000 samples, press backspace to stop. From

the Sensor Calibration Screen, record the left laser (sensor 1) Avg Height value for the floor height measurement in the appropriate space on line 2 (Height: Floor) under the “LASER SENSOR CALIBRATION CHECK” section of the Profiler Calibration Record Sheet.

11. Place the ¼” calibration block on the floor under the left laser sensor, and position the block so that the laser will reflect approximately at the center of the block. Press the Enter key to start reading the laser values. After a minimum of 1000 samples, press backspace to stop. From the Sensor Calibration Screen, record the left laser (sensor 1) Avg Height value for the block height measurement in the appropriate space on line 3 (Height: Block) under the “LASER SENSOR CALIBRATION CHECK” section of the Profiler Calibration Record Sheet.

12. Repeat steps 10 and 11 using the ½” calibration block.

13. Repeat steps 10 and 11 using the 1” calibration block.

14. Using the Height values recorded on the “LASER SENSOR CALIBRATION CHECK” section of the Profiler Calibration Record Sheet, compute the “Height: Floor - Block” values for each of the ¼”, ½”, and 1” calibration blocks by subtracting the “Height: Block” value from the “Height: Floor” value.

15. Using the “Height: Floor - Block” values recorded on the “LASER SENSOR CALIBRATION CHECK” section of the Profiler Calibration Record Sheet, compute the “Difference: Actual - Height” values for each of the ¼”, ½”, and 1” calibration blocks by subtracting the “Height: Floor - Block” value from the “Actual Block Thickness” value.

    The computed value should be less than or equal to 0.002 ft for the laser sensor to be considered working properly. If the value is greater than 0.002 ft, the trouble shooting procedure below is a suggested guide to verify and resolve any issues with the laser sensor.

16. Repeat steps 9 through 15 to perform the laser sensor calibration check on the right laser (i.e., sensor 2).

17. Press the Escape key to return to the MDR Main Menu.

If any of the “Difference: Actual – Height” values computed for the left and right sensors are greater than 0.002 ft, the following items are suggested to verify that there is an actual problem with the laser sensor. If these procedures do not successfully rule out a problem with the laser sensor(s), ICC should be contacted to assist and resolve sensor problems.

- Verify that all recorded values and computations are accurate.

- Repeat the laser sensor calibration check for the block(s) and laser that produced an unacceptable difference greater than 0.002 ft. It is possible that the block was not positioned under the laser sensor properly, or that the block was not sitting squarely on the floor. It is not necessary to repeat the calibration check for any blocks that satisfy the acceptable criteria.

- If the laser sensor calibration check was performed with the engine running, attempt to perform the calibration check (in its entirety) with the engine switched off and the profiling system plugged into house power (if possible).

- Move the profiler to another location and redo the laser sensor calibration check in its entirety.

### *3.2 CALIBRATION OF ACCELEROMETERS*

The accelerometers in the profiler should be calibrated at an interval of thirty (30) days during construction season or whenever problems are suspected. The accelerometers should be calibrated if the accelerometer check indicates accelerometer calibration factor(s) are outside the allowable range or if the bounce test indicates a potential problem with the accelerometer(s). The operator may elect to calibrate accelerometers daily prior to performing the bounce test. The accelerometers should be calibrated when repairs are performed on the accelerometer(s) or on computer cards associated with the accelerometer(s). The accelerometers should be calibrated when a full calibration check is performed on the laser sensors.

Calibration of accelerometers should be performed while the profiler is parked on a level surface. The location, where calibration is being performed, should be free of any vibrations and shielded from any environmental conditions such as gusty winds. The calibration of accelerometers can be performed when the engine of the profiler is running but ideally the engine should be turned off while the calibration is being performed. The calibration can be performed with the operator and driver sitting in the profiler seats. Alternately, the operator can stand outside of vehicle when calibration is performed and the computer monitor should be adjusted so that it can be seen from outside the profiler with the keyboard placed on the seat. Do not enter the truck, bounce or bump the profiler, or lean on the profiler during calibration. The power to the system should be turned on for about 15 minutes for the system to warm up prior to calibrating the accelerometers. The following procedure should be used to calibrate accelerometers:

1. Boot up computer following procedures described previously in Section 2.2. The MDR main menu should now be displayed on the monitor.

2. In the MDR main menu, select ‘Calibration’ to display the calibration menu. In the Calibration Menu, highlight ‘Accelerometer’ and press Enter key, and the Accelerometer Calibration Menu shown in Figure 3-2 will be displayed on the monitor. The parameters are as follows:

| | |
|---|---|
| aCcelerometer(s) | Number of configured accelerometers should be 2 of 2. |
| ACF | Accelerometer Calibration Factor |
| FGF | Filter Gain Factor |
| HPF | Integrator Filter High Pass Frequency should be 0.020. |

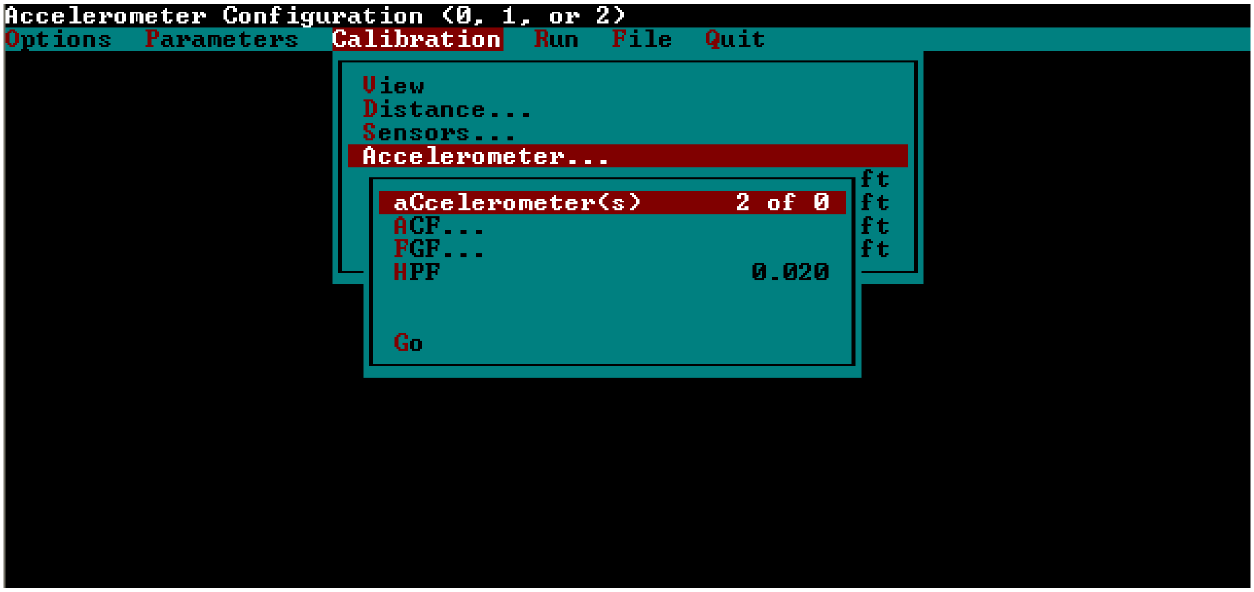


*Figure 3-2. MDR Software Accelerometer Calibration Menu.*

3. In the Accelerometer Calibration Menu, highlight ‘Go’ and press Enter key. The monitor will display an Accelerometer Calibration Screen similar to that shown in Figure 3-3.

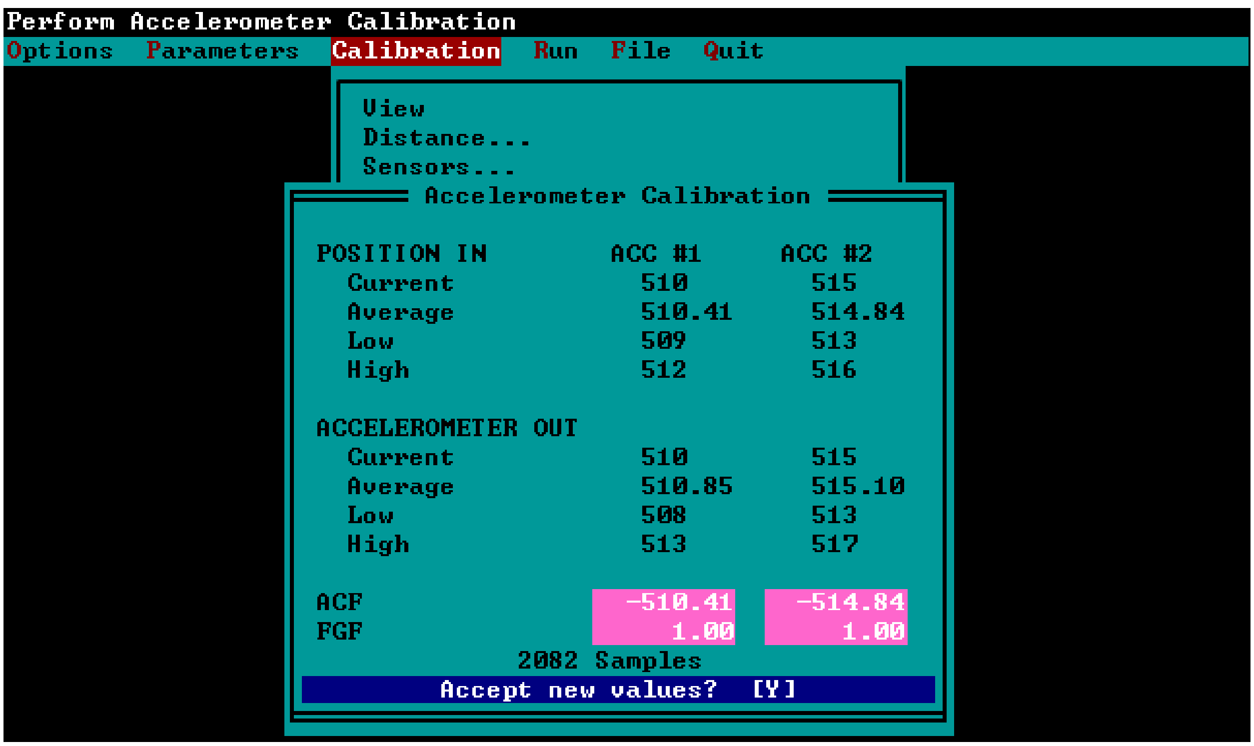


*Figure 3-3. MDR Software Accelerometer Calibration Screen.*

4. Press ‘Enter’ key and the accelerometer calibration procedure will begin to sample accelerometer measurements. After approximately 2000 samples have been taken, press ‘Backspace’ key to end calibration.

5. System will prompt the operator if the new ACF values should be accepted. The accelerometers are considered to be working properly if the ACF values are within the range 512 ± 10. If test appears to be valid, press ‘Y’ key to accept values. If test was not valid, press ‘N’ key to repeat the calibration procedure.

6. The results of the accelerometer calibration need to be recorded under the “ACCELEROMETER CALIBRATION” section on the MDT Profiler Calibration Record Sheet (Appendix B) and kept in the profiler log book. Record the calibration factor values for the right and left accelerometers prior to performing the accelerometer calibration. After completing the acceptable accelerometer calibration, record the new calibration factors for the right and left accelerometers

7. Press ‘Escape’ key to return to the MDR Main Menu.

### *3.3 BOUNCE TEST PROFILING SYSTEM*

The bounce test is a controlled-conditions procedure that uses the profiler’s built in simulation capabilities to test that the profiling system is operating properly. A bounce test will be performed every time the accelerometer calibration and laser calibration checks are performed at an interval of thirty (30) days during construction season or whenever problems are suspected. This bounce test is different than the pre-run bounce test described in Chapter 4.

The bounce test will be performed following the Laser Sensor Calibration Check and Accelerometer Calibrations described in Sections 3.1 and 3.2. Power to the electronic equipment should be turned on for about 15 minutes prior to performing any calibration or calibration checks so that the electronic equipment is allowed to warm up and stabilize.

The bounce test should be performed while the profiler is parked on a level surface. Location where the bounce test is being performed should be free of any vibrations, and shielded from any environmental conditions such as gusty winds. The bounce test can be performed when the engine of the profiler is running but ideally the engine should be turned off while the bounce test is being performed. The operator should stand outside of the vehicle when the bounce test is performed, and the computer monitor should be adjusted so that it can be seen from outside the profiler with the keyboard placed on the seat.

The results of the bounce test will be recorded under the “BOUNCE TEST” section on the MDT Profiler Calibration Record Sheet (Appendix B) and kept in the profiler log book. Additionally, the electronic data files from this bounce test will be submitted to the MDT Pavement Management Analysis Division for further analysis of the accelerometers and laser sensors.

The following procedure should be used to perform the bounce test:

1. Place brown wooden clipboards on the ground directly under the right and left laser sensors so that the lasers spots are near the center of the clipboards. Metal, plastic, or colored clipboards are not recommended as the intent of the clipboards is to have the laser sensor take height measurements off a flat neutral colored surface.

2. In the MDR Main Menu, select ‘Options’ to display the options menu. In the Options Menu, verify that the “Reference Post Display Mode” is set to “Mile” as shown in Figure 3-4.

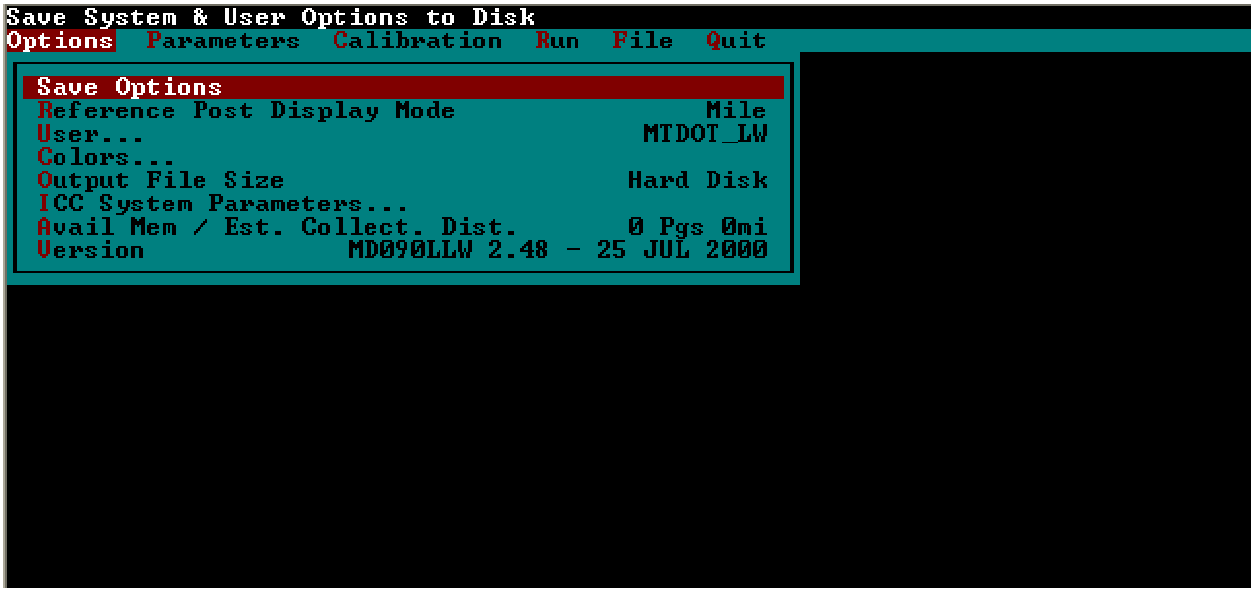


*Figure 3-4. MDR Software Options Menu for Bounce Test.*

3. In the MDR main menu, select 'Run' to display the run menu. In the Run Menu, the entries for "County," "Route," "Direction," and "Lane" do not impact the bounce test and do not need to be changed from the last data collection project. However, the "Asc/Dsc Ref Point" should be set to "+," the "daTa Directory" should be changed to "D:\BOUNCE," and the "1 File Name" should be set as the date (e.g., "14JUL05") as shown in Figure 3-5.

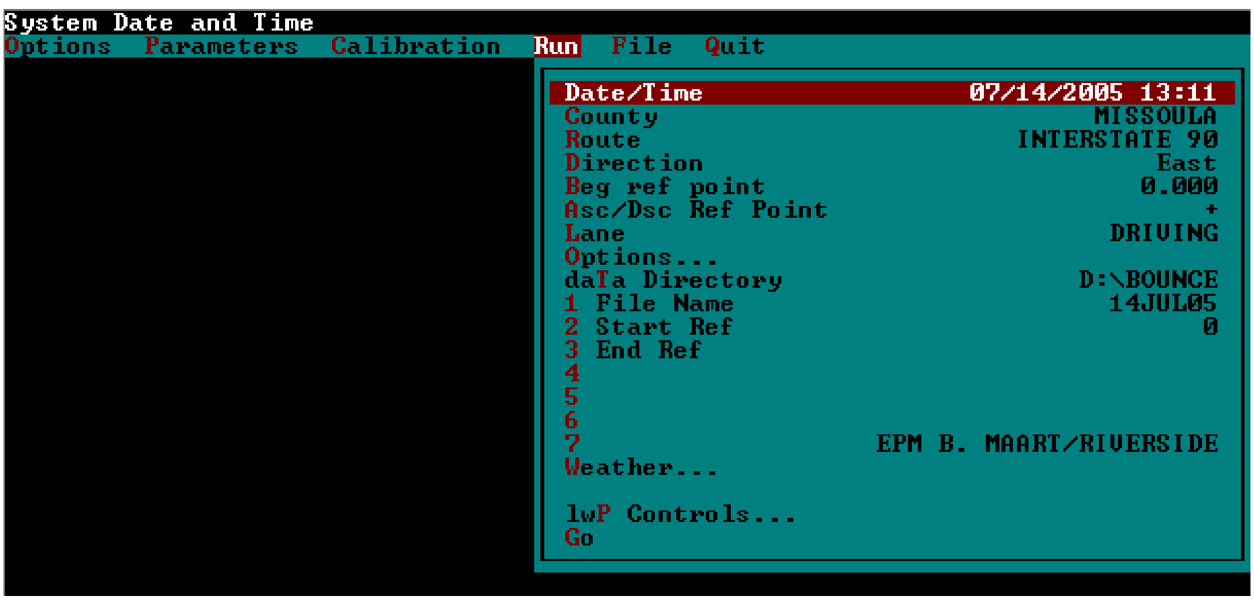


*Figure 3-5. MDR Software Run Menu for Bounce Test.*

4. In the Run Menu, select 'Options…' to display the Run Options Menu. Highlight the "DMI Simulator" option and press 'Enter' key to toggle the distance simulator to "On" as shown in Figure 3-6. The remainder of the Run Options Menu settings are described in Section 2.3. Press 'Escape' key to return to the Run Menu.


*Figure 3-6. Run Options Menu Toggling Distance Simulator On.*

5. In the Run Menu, highlight 'Go' and press 'Enter' key to begin the bounce test. The monitor will display the Run Screen similar to that shown in Figure 3-7.

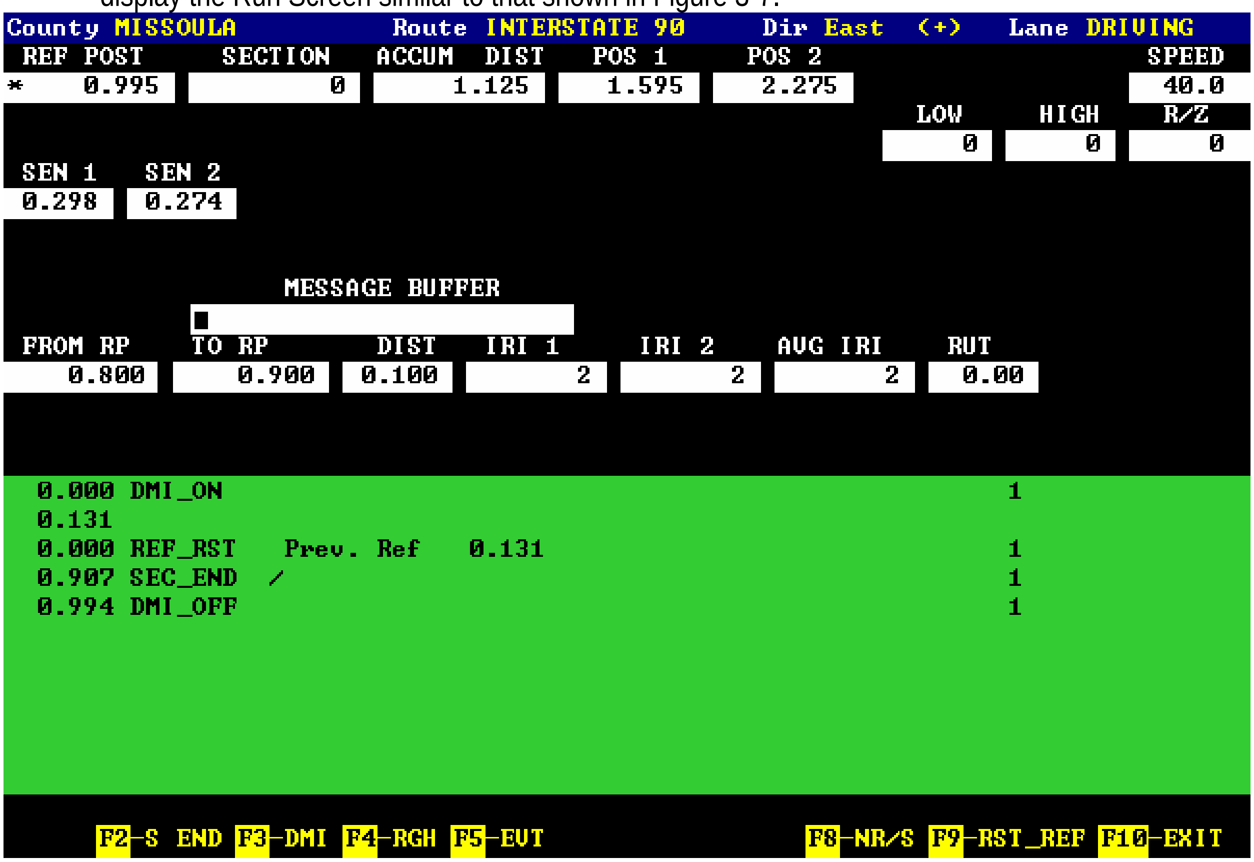


*Figure 3-7. MDR Software Run Screen for Bounce Test.*

6. Verify that the “SPEED” indicates a reasonable simulated speed. Press Page Up key to increase the speed to 70 mph (113 km/h). If the indicated speed is zero, exit the run screen and verify that the distance simulator is turned on as described in step 4 above.

7. Press the F3 key to begin simulating distance for the bounce test. The “REF POST” should indicate an ascending distance count.

8. When the “REF POST” indicates a minimum of 0.1 miles (0.16 km), press the F9 key to initiate the reference reset.

9. The profiler should remain settled for the static portion of the bounce test for a minimum of 0.5 miles (0.80 km) indicated on the “REF POST.”

10. After the “REF POST” indicates a minimum of 0.5 mi (0.80 km), the operator should begin to apply a vertical up and down motion to the center of the sensor bar on the front of the profiler. The pitching motion on the sensor bar should impart a displacement of approximately 1 in (25.4 mm) total. All efforts should be attempted to avoid any side to side or rolling motions. This dynamic portion of the bounce test should continue, without interruption, for a minimum of 30 seconds.

11. At the conclusion of the dynamic portion, press the F2 key to mark the section end of the simulated profile. The operator may elect to allow the profiler to return to a static state before stopping the simulation.

12. Press the F3 key to stop the simulated profile.

13. Press the F10 key to exit from the Run Screen. Press ‘Enter’ key to save the profile data file to the hard disk drive.

14. In the Run menu, select ‘Options…’ to display the run options menu. Highlight the “DMI Simulator” option and press the Enter key to toggle the distance simulator to “Off” as shown in Figure 3-8. Press ‘Escape’ key twice to return to the Main Menu.


*Figure 3-8. Run Options Menu Toggling Distance Simulator Off.*

15. From the Main Menu, select ‘Quit’ to exit the MDR software. At the “Do You Want to Exit System” prompt, press the ‘Y’ key.

16. At the DOS prompt, change to the directory D:\BOUNCE.

17. From the DOS prompt, type MTIRI <FILENAME> 1 and press the enter key to analyze the bounce test data. <FILENAME> is the file name set in step 4 (e.g., “14JUL05”). 1 indicates the run file number; if more than one bounce test is performed, the number of the desired bounce test should be changed to the appropriate bounce test run number.

18. When the MTIRI analysis program prompts for the IRI Report Type, enter ‘E’ for English.

19. When the MTIRI analysis program prompts for the IRI Report Interval, enter ‘1’ for 100 ft and the IRI report will be created.

20. When the MTIRI analysis program prompts how to output the IRI report, enter ‘P’ to print the file. The report can also be displayed on the monitor by entering ‘D,’ but a copy of the report should be printed and attached to the MDT Profiler Calibration Record Sheet to be kept in the profiler log book.

21. Review the IRI report for Reasonableness.

    The first 0.5 mi (0.80 km) of intervals on the report should contain IRI values reflecting the profiler in a static condition. The resulting static IRI values should be less than or equal to 5 in/mi (0.08 m/km) for the profiler to be considered functioning properly under static conditions. As long as no more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km) in either the left or right channels the profiler is considered to have satisfied the static bounce test criteria. If more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km), the bounce test should be repeated to make sure that the profiler remained completely motionless (was not bumped, moved, or otherwise disturbed) during the static portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the static IRI values are not improved.

The intervals following the static portion represent the profiler in a dynamic condition and typically have IRI values much larger than the static condition IRI values. The dynamic IRI values would typically be in the range of 20 to 45 in/mi (0.32 to 0.71 m/km) for the amount of motion imparted following this bounce test procedure. If more than three intervals of dynamic IRI values are less than 20 in/mi (0.32 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. If a majority of intervals of dynamic IRI values are significantly more than 50 in/mi (0.79 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the dynamic IRI intervals are not improved.

22. Select one interval from the static portion of the bounce test and record the resulting IRI values for the left and right sensors in the appropriate blocks on the “Static Value” line under the “BOUNCE TEST” section of the Profiler Calibration Record Sheet (Appendix B).

23. Select one interval from the dynamic portion of the bounce test and record the resulting IRI values for the left and right sensors in the appropriate blocks on the “Dynamic Value” line under the “BOUNCE TEST” section of the Profiler Calibration Record Sheet (Appendix B).

24. The electronic data files are transferred to the MDT Pavement Management Analysis Section by copying the bounce test data files to the MDT Ride Specification Share Drive. For consistency between the districts, the files will be placed in the “Calibration” subdirectory in the appropriate district directory on the Share Drive. After copying the electronic data files to the Share Drive, the MDT Pavement Management Analysis Section should be notified of the new bounce test data requiring analysis.

If the review of the IRI report or the additional data review performed by the MDT Pavement Management Analysis Section indicates potential problems with the profiling system, ICC should be contacted for assistance in resolving any problems.

### *3.4 CALIBRATION OF DMI*

The DMI should be calibrated at an interval of thirty (30) days during construction season or whenever problems are suspected. The DMI should also be calibrated when tires are replaced, suspension repairs are performed, or when wheels are rotated or aligned. The DMI should be calibrated when repairs are performed on the DMI or to computer cards associated with the DMI.

The DMI is calibrated by driving the vehicle over a known distance to calculate the Distance Calibration Factor (DCF). The operator enters the actual distance traveled in the calibration menu and the computer calculates the DCF. An accurately measured section that is approximately one mile long should be used to calibrate the DMI. The section should be measured with a standard surveying tape using standard surveying procedures or laid out using an electronic distance measurement (EDM) system. Each district should have a calibration site set up. This section should be located on a straight portion of roadway that is reasonably level and has low traffic volume.

Prior to driving the profiler, the operator should check the tire pressure (cold) to ensure that the tire pressure of the rear tires are at the truck and tire manufacturers' recommended pressures. The operator should drive the vehicle for about 4 to 5 mi (6 to 8 km) at highway speeds prior to calibration so that the tires can warm up. Based on local weather conditions (e.g., cold weather) the operator may need to increase the distance the vehicle should be driven to warm up the tires.

The following procedure should be used to calibrate the DMI:

1. Power up the profile system and boot the computer using procedures outlined previously in Section 2.2.

2. Check and adjust if necessary the rear tire pressures to verify reasonable values that are consistent with the manufacturer specified cold tire pressures. The DMI calibration should only be performed when the tires have been warmed sufficiently to maintain a stable pressure throughout the time required to perform the DMI calibration.

3. In the MDR main menu, choose 'Calibration' to bring up the Calibration Menu and then highlight 'Distance' and press 'Enter' key as shown in Figure 3-9. The screen will display the current DCF. The DCF is a maximum of five (5) numbers followed by a letter. The letter represents the following:

   C Entry was entered by completing the calibration process.
   E DCF has been entered into the system.
   U No calibration has been performed by operator.

   Note: MDT will only accept DCF values attained through the calibration process.

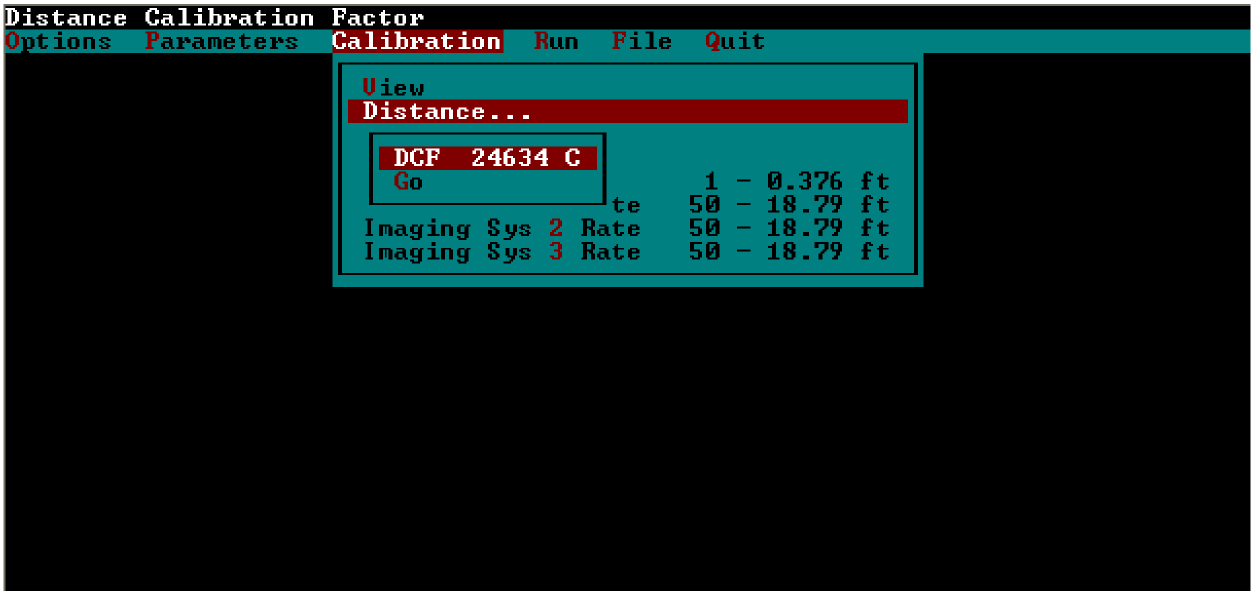


*Figure 3-9. MDR Software Distance Calibration Menu.*

4. In the Distance Menu highlight 'Go' and press 'Enter' key. The system will then prompt the operator for the Calibration Distance. Enter the length of the calibration section and press 'Enter' key (e.g., 5280). The system will then prompt the operator for the tire pressure. Enter the current, warm tire pressure and press 'Enter' key (e.g., 50). The distance calibration screen shown in Figure 3-10 will now be displayed on the monitor.


*Figure 3-10. MDR Software Distance Calibration Screen Before Performing DMI Calibration.*

The following steps are a coordinated effort between the operator and driver. The profiler will be driven over the distance calibration course, and the operator will manually mark in the computer when the profiler passes over the beginning and ending points of the course. During the calibration, the profiler must be driven smoothly and as straight as possible; all accelerations and decelerations must be constant; and the profiler should not be placed into reverse between the times when the start mark and end mark are noted in the computer.

5. The F3 key should be pressed to activate the Distance Calibration Test mode.

6. The profiler should be driven near the starting point of the distance calibration course. When the profiler is approximately three feet from the starting point, the profiler should be gradually rolled forward until a mark on the profiler is aligned with the mark on the pavement from the constant vantage point of the operator. At the same time as the mark on the profiler aligns with the mark on the pavement, the operator should press the 'Enter' key to begin the pulse counts for the distance calibration.

7. The profiler should be gradually accelerated until the profiler has attained a reasonable speed to traverse the distance calibration course. As the end of the course is neared, the profiler should be gradually slowed.

8. When the profiler is approximately ten (10) ft from the ending point of the distance calibration course, the profiler should be gradually rolled forward until the mark on the profiler is aligned with the mark on the pavement from the constant vantage point of the operator. At the same time as the mark on the profiler aligns with the mark on the pavement, the operator should press the 'Backspace' key to stop the pulse counts for the distance calibration. The MDR software automatically computes the DCF from the number of pulse counts and displays the values on the screen.

9. Steps 5 through 8 should be repeated five more times until six calibration attempts have been completed. When six calibration runs have been obtained, the monitor will display a screen similar to that shown in Figure 3-11.

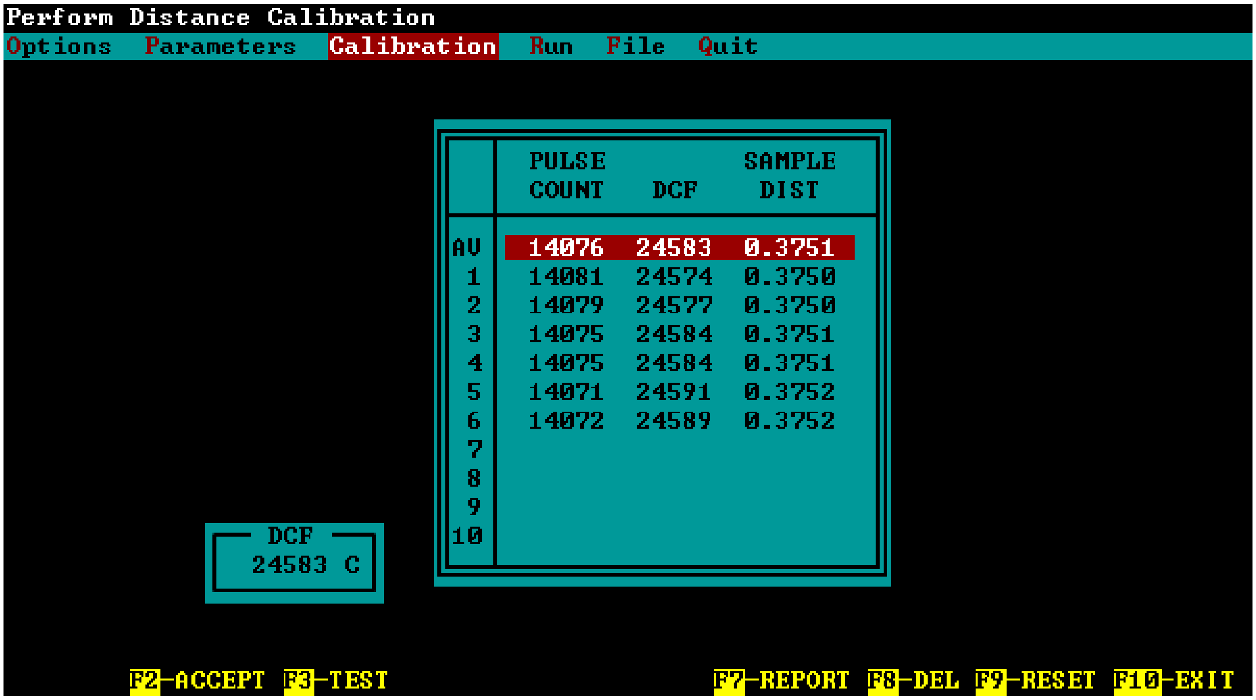


*Figure 3-11. MDR Software Calibration Screen After Performing DMI Calibration.*

10. Acceptability of the DMI Calibration:

    This is determined by comparing the six "PULSE COUNT" values resulting from the six calibration attempts to the "PULSE COUNT" value in the "AV" row. All six calibration attempts should have values that are within ± 10 of the average pulse count. For example: If the average pulse count is 14076, then all six pulse counts from the six calibration attempts must be within 14066 and 14086.

    If any of the six calibration attempts is outside the acceptable limits, then the unacceptable runs should be highlighted and deleted by pressing the F8 key. Following the deletion of the unacceptable runs, new calibration attempts (as detailed in steps 5 through 8) should be made for each run that was deleted. The intention is to only delete the poor runs and replace with new runs, and NOT re-run a complete set of 6 runs.

11. The new DCF value computed during DMI calibration has to be saved. Use the arrow keys to highlight the average shown at the top of the list and press the F2 key to accept the new DCF value. Press 'Enter' key to store.

    If for any reason the DCF values are unacceptable, press the F9 key. A verification line will appear at the top of the screen. The operator must then press the 'Y' key for deletion. This will wipe out all DCF's and reset the beginning of the distance calibration procedure.

    The results of the DMI calibration need to be recorded under the "DMI CALIBRATION" section on the MDT Profiler Calibration Record Sheet (Appendix B) and kept in the profiler log book. Record the DCF values for the prior calibration, the new average, and the six acceptable calibration attempts. Also record the rear tire pressures values from before the DMI calibration was started and after the six acceptable calibration attempts were completed.

12. Press F10 to exit the Distance Calibration. The system will prompt 'Do You Want to Exit?' Press the 'Y' key to return to the MDR Main Menu.

# 4.0 FIELD OPERATIONS

The following sections describe the procedures to be followed each day prior to and during data collection with respect to pre-run checks of the profiling equipment and actual profiling activities.

## *4.1 PRE-RUN CHECKS*

MDT has prescribed maintenance plans pertaining to the profiler's mechanical components. Any required maintenance checks should be performed on the profiler prior to any movement of the profiler.

Additionally, the profiling equipment on the profiler requires three pre-run checks that verify proper operation of the profile sensors. The next three sections describe the Laser Sensor Check, Accelerometer Calibration Check, and Bounce Test that should be performed prior to any profile data collection.

### 4.1.1 LASER SENSOR CHECK

A calibration check of the laser sensors is performed each day prior to data collection. In this procedure, the laser sensors are checked to see if they can accurately measure within the specified height tolerance by using calibration blocks. This procedure only checks the accuracy of the laser sensor over a ½" (12.7 mm) measuring range. This check is referred to as the Pre-Run Calibration Check of laser sensors and is different than the Full Calibration Check described in Chapter 3, which is performed every thirty (30) days during construction season. A full calibration check of the laser sensors must be performed whenever problems are suspected on the laser sensors or when a sensor is repaired or replaced.

The location where the pre-run calibration check is performed should protect profiler from wind and other vibrations. The pavement surface should be as level as possible and lighting conditions should be consistent from sensor to sensor (i.e., face profiler away from the sun). An external power source should be used whenever possible.

Gently clean each lens following the guidelines described in Chapter 2. When cleaning the lenses, extreme care should be taken to prevent scratching of the lenses.

Power to the electronic equipment should be turned on for about 15 minutes prior to performing any calibration or calibration checks so that the electronic equipment is allowed to warm up and stabilize.

The laser sensor check has the following steps:

1. The operator should be outside of the profiler when the calibration check is performed. Adjust the computer monitor so that it can be seen from outside the vehicle, and the keyboard should be placed on the seat of the profiler. Do not enter the profiler, bounce or bump the profiler, or lean on the profiler during the calibration check.

2. In the MDR Main Menu, select ‘Calibration’ to display the Calibration Menu. Highlight ‘Sensors…’ and press ‘Enter’ key to display the Calibration Sensors Menu.

3. Highlight ‘Cal Temp’ selection and press ‘Enter’ key. Enter an accurate air temperature value ±3°F and press ‘Enter’ key.

4. In the Calibration Sensors Menu, make sure that all parameters match the settings described in Section 2.3.

5. In the Calibration Sensors Menu, highlight ‘Go’ and press ‘Enter’ key. The monitor will display the sensor calibration screen similar to Figure 4-1.

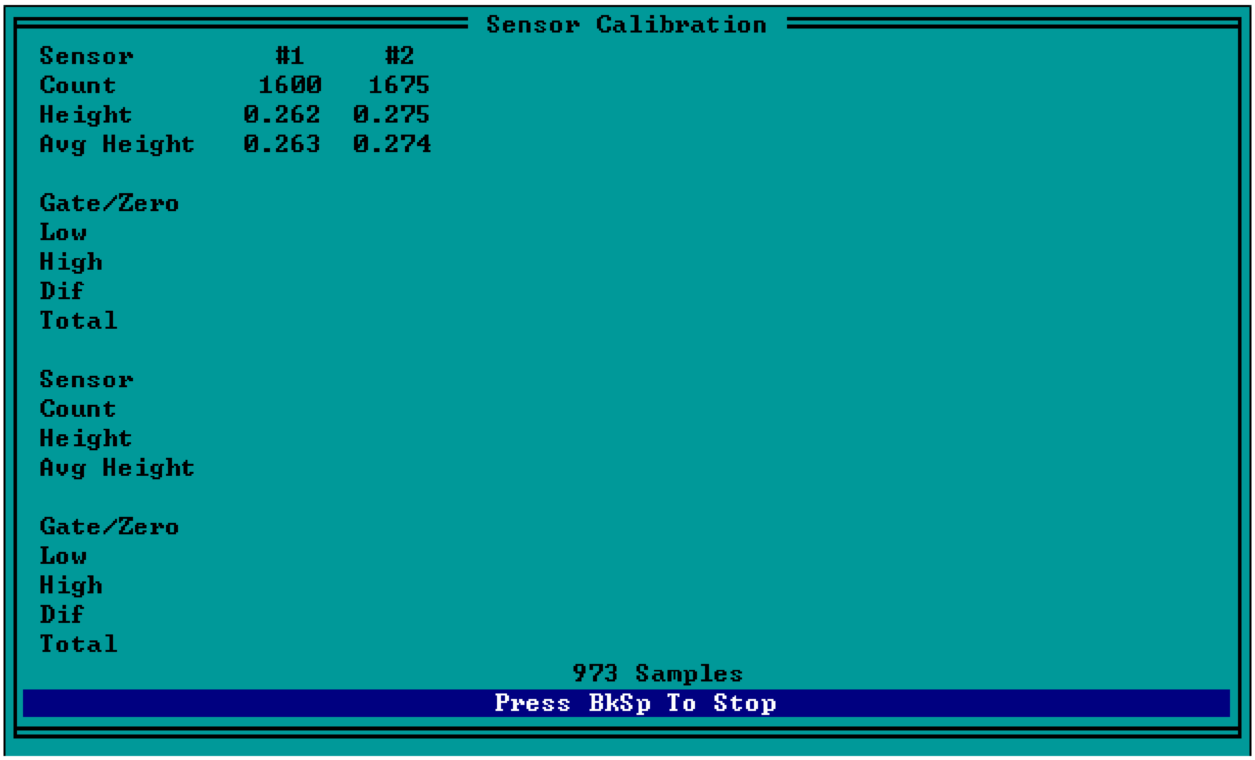


*Figure 4-1. MDR Software Sensor Calibration Screen for Pre-Run Laser Sensor Check.*

6. Verify that no blocks, objects, or debris are directly under the laser sensors. Press the Enter key to start reading the laser values. After a minimum of 1000 samples, press backspace to stop. From the Sensor Calibration Screen, record the left laser (sensor 1) Avg Height value for the ground height measurement.

7. Place the ½” calibration block on the ground under the left laser sensor, and position the block so that the laser will reflect approximately at the center of the block. Press the Enter key to start reading the laser values. After a minimum of 1000 samples, press backspace to stop. From the Sensor Calibration Screen, record the left laser (sensor 1) Avg Height value for the block height measurement.

8. Subtract the block height measurement value noted in step 7 from the ground height measurement value noted in step 6. Compare the difference to the actual block thickness (Section 3.1). The difference between the height measurement values compared to the block thickness should be less than or equal to 0.002 ft for the laser sensor to be considered working properly. If the value is greater than 0.002 ft, the trouble shooting procedure below is a suggested guide to verify and resolve any issues with the laser sensor.

9. Repeat steps 6 through 8 for the right laser (sensor 2).

10. Press ‘Escape’ key to return to the MDR Main Menu.

The following items are suggested to verify that there is an actual problem with a laser sensor. If these procedures do not successfully rule out a problem with the laser sensor(s), ICC should be contacted to assist and resolve sensor problems.

- Verify that all recorded values and computations are accurate.

- Repeat the laser sensor calibration check for the block(s) and laser that produced an unacceptable difference greater than 0.002 ft. It is possible that the block was not positioned under the laser sensor properly, or that the block was not sitting squarely on the floor. It is not necessary to repeat the calibration check for any blocks that satisfy the acceptable criteria.

- If the laser sensor calibration check was performed with the engine running, attempt to perform the calibration check (in its entirety) with the engine switched off and the profiling system plugged into house power (if possible).

- Move the profiler to another location and redo the laser sensor calibration check in its entirety.

#### 4.1.2 ACCELEROMETER CHECK

A calibration check of the accelerometers is performed each day prior to data collection and anytime the system has been previously shut down. The accelerometers in the profiler should be calibrated as described in Chapter 3. The accelerometers should be calibrated if the accelerometer check indicates accelerometer calibration factor(s) are outside the allowable range or if the bounce test indicates a potential problem with the accelerometer(s). The accelerometers should be calibrated when repairs are performed on the accelerometer(s) or on computer cards associated with the accelerometer(s).

The accelerometer calibration check should be performed while the profiler is parked on a level surface. Location where calibration check is being performed should be free of any vibrations, and shielded from any environmental conditions such as gusty winds. The accelerometer calibration check can be performed when the engine of the profiler is running, but ideally the engine should be turned off while the check is being performed. The calibration check should be performed with the operator and driver sitting in the profiler seats. Do not enter the truck, bounce or bump the profiler, or lean on the profiler during the calibration check. The power to the system should be turned on for about 15 minutes for the system to warm up prior to the accelerometer calibration check. The following procedure should be followed to perform the accelerometer calibration check:

1. Boot up computer following procedures described previously in Section 2.2. The MDR Main Menu should now be displayed on the monitor.
2. In the MDR Main Menu, select 'Calibration' to display the Calibration Menu. In the Calibration Menu, highlight 'Accelerometer…' and press 'Enter' key, and the Accelerometer Calibration Menu shown in Figure 4-2 will be displayed on the monitor. Please note that accelerometer line on top of menu should read "2 of 2".

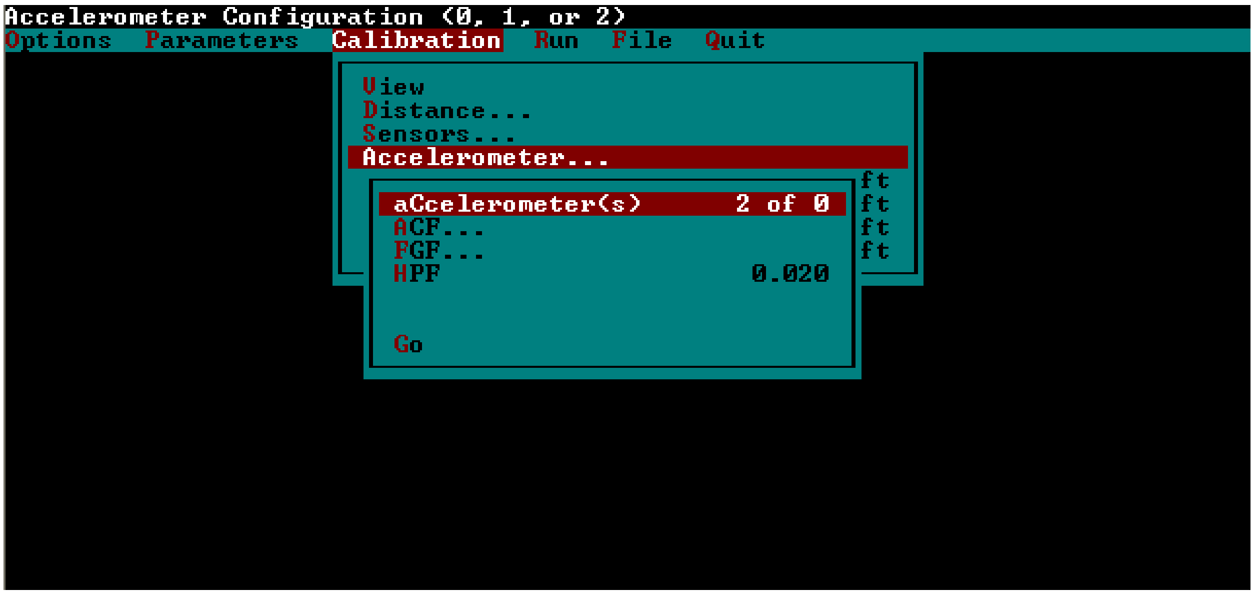


*Figure 4-2. MDR Software Accelerometer Calibration Menu for Accelerometer Check.*

3. In the Accelerometer Calibration Menu, highlight 'Go' and press 'Enter' key. The monitor will display an Accelerometer Calibration Screen similar to that shown in Figure 4-3.

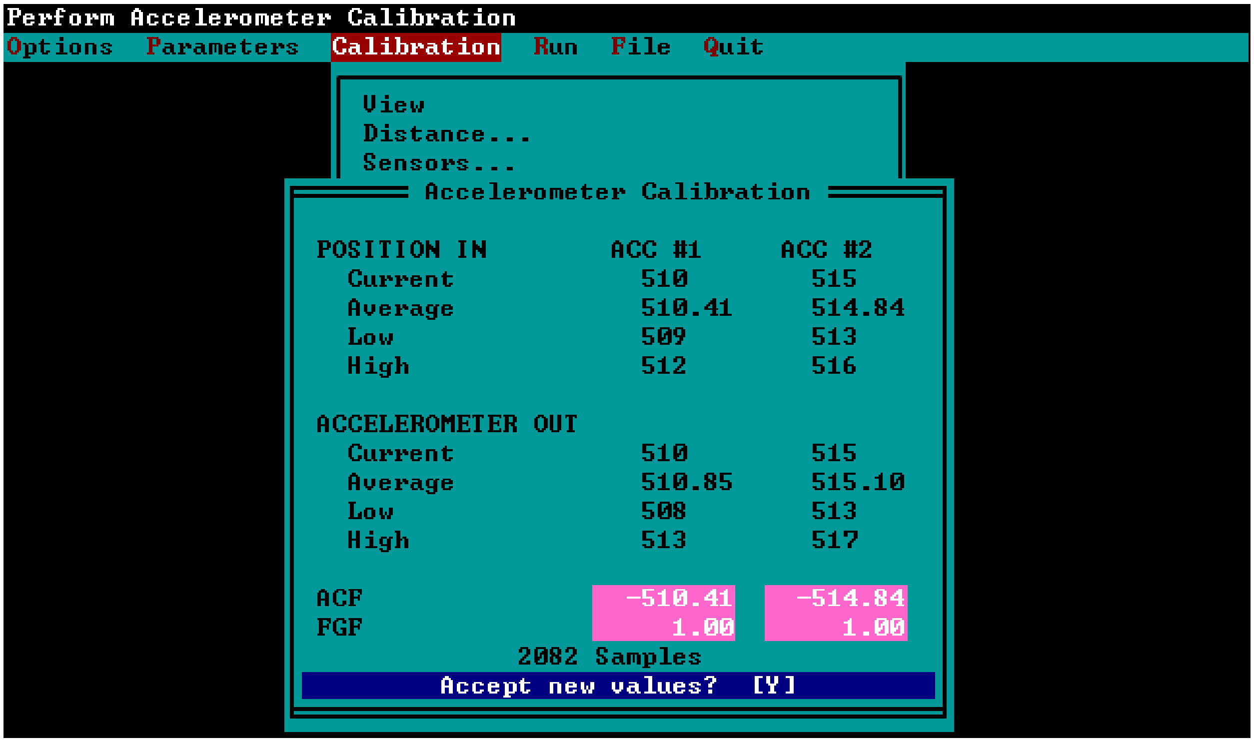


*Figure 4-3. MDR Software Accelerometer Calibration Screen for Accelerometer Check.*

4. Press 'Enter' key and the accelerometer calibration procedure will begin to sample accelerometer measurements. After approximately 2000 samples have been taken, press 'Backspace' key to end calibration.

5. System will prompt the operator if the new ACF values should be accepted. The accelerometers are considered to be working properly if the ACF values are within the range 512 ± 10. If test appears to be valid, press 'N' key because the daily accelerometer check is being performed only to test the accelerometers for proper operation.

   If the test was not valid, press 'N' key and repeat steps 3 and 4 to test the accelerometers again. If the repeat accelerometer calibration checks continue to produce results outside the acceptable range, perform a full calibration of the accelerometers as described in Section 3.2.

6. Press 'Escape' key to return to the MDR Main Menu.

### 4.1.3 Pre-Run Bounce Test

The bounce test is performed to verify that height sensors and accelerometers in the profiler are functioning properly. The pre-run bounce test should be performed every day prior to data collection. This bounce test consists of two parts, a static test and a dynamic test. Both the static and dynamic tests are combined into one test. This bounce test is different than the bounce test described in Chapter 3. The bounce test is performed following the Laser Sensor Calibration Check and Accelerometer Calibration Check described in Sections 4.1.1 and 4.1.2.

Power to the electronic equipment should be turned on for about 15 minutes prior to performing any calibration or calibration checks so that the electronic equipment is allowed to warm up and stabilize.

The bounce test should be performed while the profiler is parked on a level surface. Location where the bounce test is being performed should be free of any vibrations, and shielded from any environmental conditions such as gusty winds. The bounce test can be performed when the engine of the profiler is running but ideally the engine should be turned off while the bounce test is being performed. The operator should stand outside of the vehicle when the bounce test is performed, and the computer monitor should be adjusted so that it can be seen from outside the profiler with the keyboard placed on the seat.

The following procedure should be used to perform the bounce test:

1. Place brown wooden clipboards on the ground directly under the right and left laser sensors, so that the lasers spots are near the center of the clipboards. Metal, plastic, or colored clipboards are not recommended, as the intent is to have the laser sensor take height measurements off a flat neutral colored surface.

2. In the MDR Main Menu, select ‘Options’ to display the Options Menu. In the Options Menu, verify that the “Reference Post Display Mode” is set to “Mile” as shown in Figure 4-4.

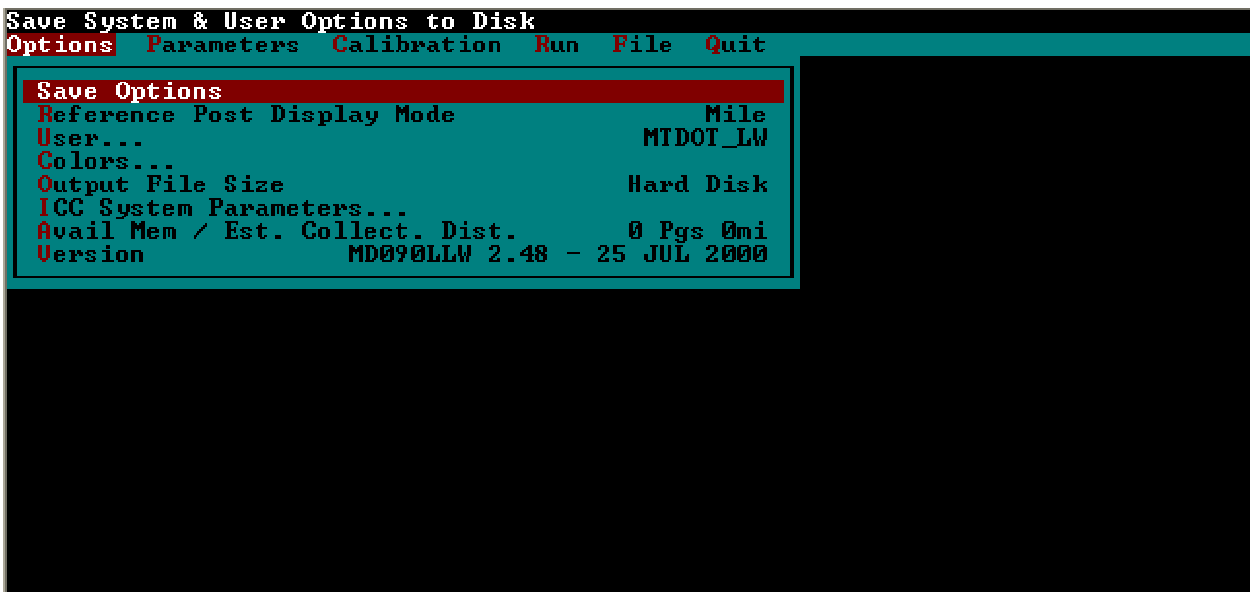

*Figure 4-4. MDR Software Options Menu for Pre-Run Bounce Test.*

3. In the MDR Main Menu, select ‘Run’ to display the Run Menu. In the Run Menu, the entries for “County,” “Route,” “Direction,” and “Lane” do not impact the bounce test and do not need to be changed from the last data collection project. However, the “Asc/Dsc Ref Point” should be set to “+,” the “daTa Directory” should be changed to “D:\BOUNCE,” and the “1 File Name” should be set as the date (e.g., “14JUL05”) as shown in Figure 4-5.


*Figure 4-5. MDR Software Run Menu for Pre-Run Bounce Test.*

4. In the Run Menu, select ‘Options…’ to display the Run Options Menu. Highlight the “DMI Simulator” option and press ‘Enter’ key to toggle the distance simulator to “On” as shown in Figure 4-6. The remainder of the Run Options settings are described in Section 2.3. Press ‘Escape’ key to return to the Run Menu.


*Figure 4-6. Run Options Menu Toggling Distance Simulator On for Pre-Run Bounce Test.*

5. In the Run Menu, highlight ‘Go’ and press ‘Enter’ key to begin the bounce test. The monitor will display the Run Screen similar to that shown in Figure 4-7.

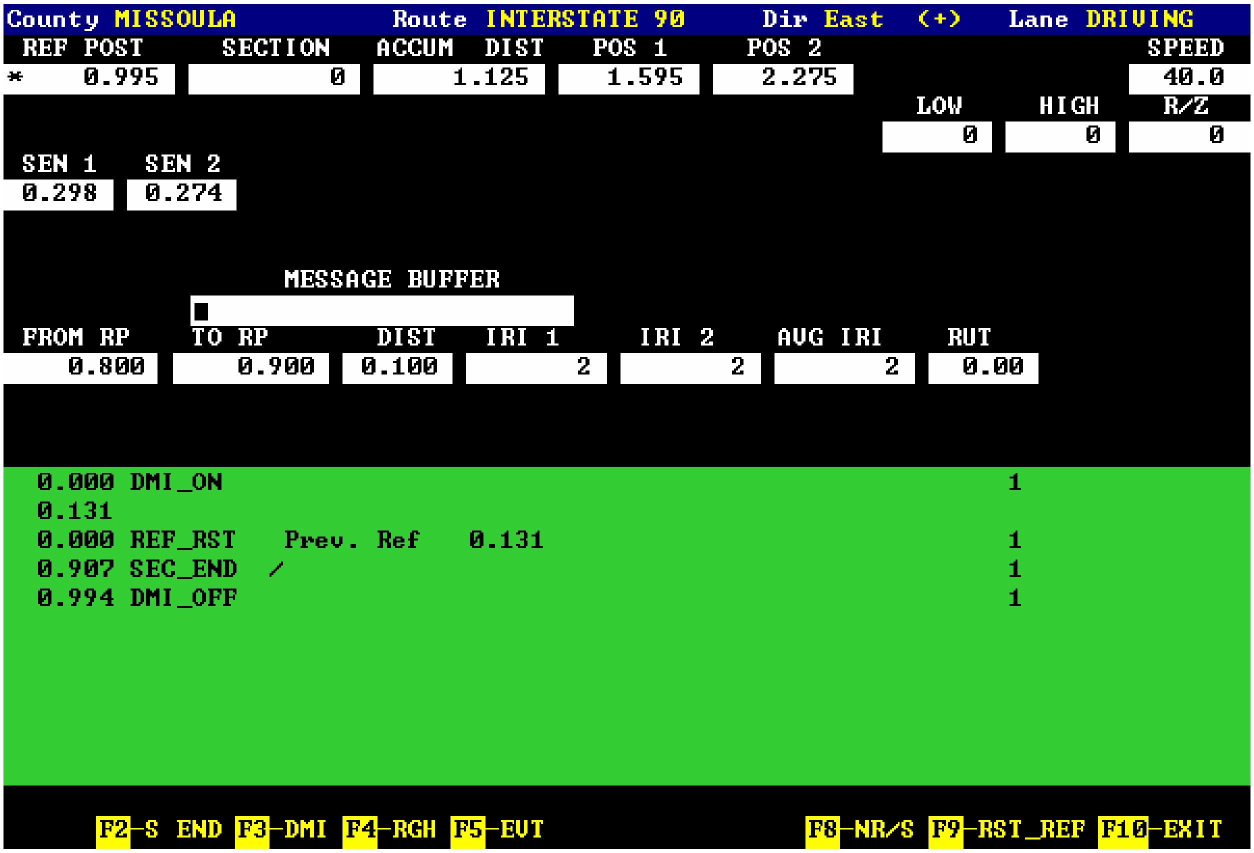

*Figure 4-7. MDR Software Run Screen for Pre-Run Bounce Test.*

6. Verify that the "SPEED" indicates a reasonable simulated speed. Press Page Up key to increase the speed to 70 mph (113 km/h). If the indicated speed is zero, exit the run screen and verify that the distance simulator is turned on as described in step 4 above.

7. Press the F3 key to begin simulating distance for the bounce test. The "REF POST" should indicate an ascending distance count.

8. When the "REF POST" indicates a minimum of 0.1 miles (0.16 km), press the F9 key to initiate the reference reset.

9. The profiler should remain settled for the static portion of the bounce test for a minimum of 0.5 miles (0.80 km) indicated on the "REF POST."

10. After the "REF POST" indicates a minimum of 0.5 miles (0.80 km), the operator should begin to apply a vertical up and down motion to the center of the sensor bar on the front of the profiler. The pitching motion on the sensor bar should impart a displacement of approximately 1 inch (25.4 mm) total, and all efforts should be attempted to avoid any side to side or rolling motions. This dynamic portion of the bounce test should continue, without interruption, for a minimum of 30 seconds.

11. At the conclusion of the dynamic portion, press the F2 key to mark the section end of the simulated profile.

12. Press the F3 key to stop the simulated profile.

13. Press the F10 key to exit from the Run Screen. Press 'Enter' key to save the profile data file to the hard disk drive.

14. In the Run Menu, select 'Options…' to display the Run Options Menu. Highlight the "DMI Simulator" option and press 'Enter' key to toggle the distance simulator to "Off" as shown in Figure 4-8. Press 'Escape' key twice to return to the Main Menu.


*Figure 4-8. Run Options Menu Toggling Distance Simulator Off for Pre-Run Bounce Test.*

15. From the Main Menu, select 'Quit' to exit the MDR software. At the "Do You Want to Exit System" prompt, press the 'Y' key.

16. At the DOS prompt, change to the directory D:\BOUNCE.

17. From the DOS prompt, type MTIRI <FILENAME> 1 and press the enter key to analyze the bounce test data. <FILENAME> is the file name set in step 4 (e.g., "14JUL05"). "1" indicates the run file number; if more than one bounce test is performed, the number of the desired bounce test should be changed to the appropriate bounce test run number.

18. When the MTIRI analysis program prompts for the IRI Report Type, enter 'E' for English.

19. When the MTIRI analysis program prompts for the IRI Report Interval, enter '1' for 100 feet and the IRI report will be created.

20. When the MTIRI analysis program prompts how to output the IRI report, enter 'P' to print the file. The report can also be displayed on the monitor by entering 'D.'

21. Review the IRI report for Reasonableness.
    The first 0.5 mi (0.80 km) of intervals on the report should contain IRI values reflecting the profiler in a static condition. The resulting static IRI values should be less than or equal to 5 in/mi (0.08 m/km) for the profiler to be considered functioning properly under static conditions. As long as no more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km) in either the left or right channels the profiler is considered to have satisfied the static bounce test criteria. If more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km), the bounce test should be repeated to make sure that the profiler remained completely motionless (was not bumped, moved, or otherwise disturbed) during the static portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the static IRI values are not improved.

    The intervals following the static portion represent the profiler in a dynamic condition and typically have IRI values much larger than the static condition IRI values. The dynamic IRI values would typically be in the range of 20 to 45 in/mi (0.32 to 0.71 m/km) for the amount of motion imparted following this bounce test procedure. If more than three intervals of dynamic IRI values are less than 20 in/mi (0.32 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. If a majority of intervals of dynamic IRI values are significantly more than 50 in/mi (0.79 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the dynamic IRI intervals are not improved.

    If the bounce test indicates potential problems with the profiling system, ICC should be contacted for assistance in resolving any problems.

## *4.2 DATA COLLECTION*

This section describes the procedures for performing profile data collection. Analysis of the profile data is described in Chapter 5.

### 4.2.1 PROFILER SETUP

Prior to collecting profile data at a site, the driver and operator need to prepare the profiler for data collection. Powering and boot-up procedures for the profiler computer and sensors are described in Chapter 2. The settings and parameters for the profile data collection MDR software are also described in Chapter 2.

The MDT Profiler Field Activity Report (Appendix B) is to be completed for each project profiled. This form will be kept in the profiler's log book and is a record of the profiling activities for the project.

Upon arrival at the project to be profiled, the driver and operator should coordinate with the Engineering Project Manager (EPM) to identify the beginning and ending points of the project, and the locations of any bridges or other significant events. The information gathered by performing a pre-survey of the project will be used to fill the required parts of the Profiler Field Activity Report and complete the setup of the MDR software for profiling.

### 4.2.2 File Naming Convention

The file naming convention to be used in specifying the name of the data file in the MDR software is described in this section. Failure to adhere to the file naming convention could create additional work in generating reports and archiving files. The file name should consist of six characters, where the characters one to four represent the Control Number (e.g., 1022, 1513, etc.), character five represents the direction of travel (i.e., N, S, E, W), and character six represents the lane of travel (i.e., D=Driving, P=Passing, or T=Turning). The following are examples of valid data file names:

1022ND: Control Number 1022, northbound direction, driving lane.
1513ST: Control Number 1513, southbound direction, turning lane.
3611EP: Control Number 3611, eastbound direction, passing lane.

Additionally, the profile data files will be saved to a directory specified by the user. The file directory will be the project control number. The following are examples of file directories using project control numbers:

D:\1022
D:\1513
D:\3611

### 4.2.3 Operating Speed

A constant vehicle speed of 50 mph (80 km/h) should be maintained during a profile measurement run. If the maximum constant speed attainable is less than 50 mph (80 km/h) due to either traffic congestion or safety constraints then a lower speed depending on prevailing conditions should be selected. If the speed limit at the site is less than 50 mph (80 km/h), the site should be profiled at the posted speed limit. If traffic traveling at high speeds is encountered at a site, it is permissible to increase the profiling speed up to 65 mph (105 km/h). If the site is relatively flat, cruise control should be used to maintain a uniform speed. It is important to avoid changes in speed during a profile run that may jolt the vehicle or cause it to pitch on its suspension. Change in throttle pressure or use of brakes to correct vehicle speed should be applied slowly and smoothly.

### 4.2.4 Event Initiation

During data collection, the MDR program uses an ‘event mark’ to record a Reference Reset in the event file. Event marks are generated by the photocell or manually by pressing the ‘F9’ key. Cones with the reflective marker should be placed on the shoulder at the beginning and end of the project to activate the photocell. The leave edge of the reflective marker should be aligned with the leave edge of the project’s limits. Section 2.1.6 contains additional information about the operation of the photocell. The preferred method to initiate profile data collection is through the use of the photocell detecting the reflective marker at the beginning of the project.

If it is not feasible to use the photocell to initiate and stop the profile data collection, data collection can be initiated and stopped manually. When manually initiating and stopping profile data collection, cones should be placed at the beginning and end of the project to be used as reference points by the operator. To initiate profile data collection manually, press the ‘F9’ key to perform the Reference Reset as close as practical to the beginning of the project. To stop the profile data collection manually, press the ‘F2’ or ‘F9’ key as close as practical to the end of the project.

#### 4.2.5 Excluded Areas

Bridges and other specific locations identified by the EPM need to be "marked" in the profile data so that the areas may be excluded from the roughness computations as defined in the Montana Ride Specification. The operator will denote the beginning and ending of the excluded location by pressing the 'F4' key as the profiler traverses the location during the profile runs. Specifically, the operator will press the 'F4' key approximately 10 feet (3 m) before the beginning of the excluded area and will press the 'F4' key again approximately 10 feet (3 m) before passing the end of the excluded area.

#### 4.2.6 Loading & Saving Files

Saving files to the hard disk, Zip disk, or floppy disk, or loading files from the hard disk, Zip disk, or floppy disk should not be done while the vehicle is in motion. At the completion of a profile run, the driver should pull over to a safe location and come to a complete stop and then save data file to hard disk.

#### 4.2.7 Turnarounds

Follow applicable laws in Montana regarding use of median turnarounds.

#### 4.2.8 Flashing Signals & Safety Equipment

The profiler is equipped with a flashing signal bar. The flashing signal bar should be turned on during testing and used according to MDT policies. All relevant MDT safety policies should be followed without exception.

#### 4.2.9 Inclement Weather & Other Interference

Inclement weather conditions (e.g., rain, snow, heavy cross winds) can interfere with the acquisition of acceptable ride data. Profile measurements should only be performed on dry pavements. In some cases, it may be possible to perform measurements on a damp pavement with no visible accumulation of surface water. Under such circumstances, the data should be monitored closely for run to run variations and potential data spikes.

When reviewing data, operator should keep in mind that spikes could occur due to pavement conditions (e.g., potholes, transverse cracks, bumps) and electronic interferences. Changing reflectivity on a drying pavement due to differences in brightness of pavement (e.g., light and dark areas) may yield results inconsistent with data collected on uniformly colored dry pavements. Run to run variations in data collected under such conditions should be carefully evaluated. If problems are suspected, profile measurements should be suspended until pavement is completely dry.

Electromagnetic radiation from radar or radio transmitters may also affect data recorded by the profiler. If this occurs, the operator should attempt to identify. Source can be contacted to ascertain suitable testing time (i.e., time when source is off).

#### 4.2.10 Profiling Test Section

Once the setup information has been entered into the MDR software and the profiling equipment has warmed up sufficiently, the profiler is ready to begin profiling. The following procedures should be followed to get an acceptable set of profile data. In these procedures keys on either the keyboard or the handheld event pad can be used.

1. From the Main Menu, highlight ‘Run’ and press ‘Enter’ key to display the Run Menu as shown in Figure 4-9.

2. From the Run Menu, highlight ‘Go’ and press ‘Enter’ key to display the Run Screen as shown in Figure 4-10.

3. The driver should attain a constant test speed of 50 mph (80 km/h) at least 575 ft (175 m) before the beginning of the test section and align the profiler with the wheel paths of the lane. A speed different from 50 mph (80 km/h) may be used depending on site conditions.

4. Press the F3 key to start the DMI about 500 ft (150 m) before the start of the test section. The profiler should have attained its constant testing speed prior to pressing the F3 key.

*Figure 4-9. MDR Software Run Menu for Profiling.*

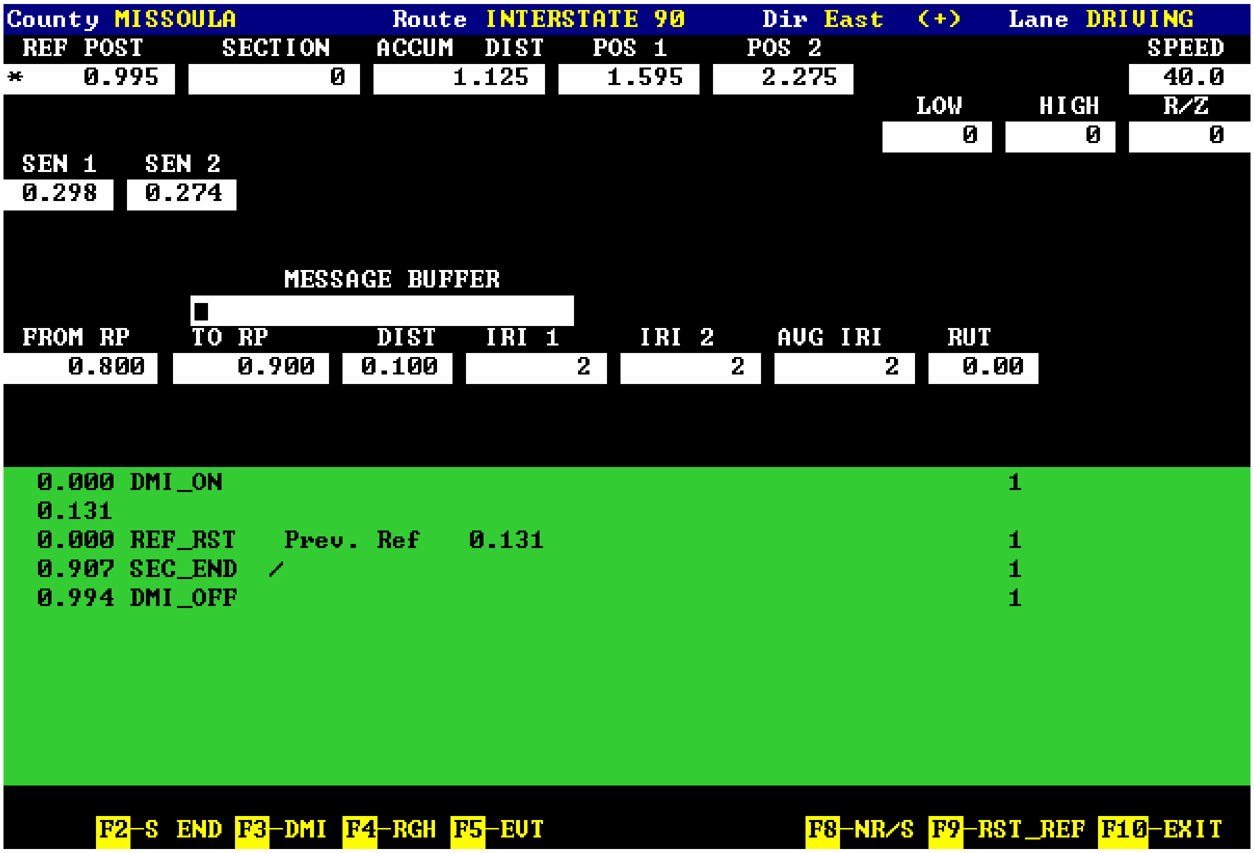

*Figure 4-10. MDR Software Run Screen for Profiling.*

5. When passing the target cone at the start of the project the system should show a “Reference Reset” and will now be collecting data. Continue driving to the end of the project.

6. When passing the target cone at the end of the project, the system should show a “Section” mark.

7. Press the F2 or F9 key to place a “Section End” mark in the data file and then press the F3 key to stop the data collection.

8. Press the F10 key to exit the Run Screen and save the profile data.

9. After saving the data file, the system returns to the MDR Run Menu. This represents a completed data collection run. To continue making profile runs, go back to step 2.

In order to assure quality profile data, a minimum of two runs (and a maximum of five runs) will be completed for each lane of the project. Each lane has a unique file name and the operator should verify that the file name is properly established prior to beginning the profile run.

Chapter 5 discusses the process for analyzing the profile data. After completing the profile runs for all lanes, the profile data will be analyzed for IRI and bump locations. Acceptability of the profile runs will be determined based on the IRI analysis.

#### 4.2.11 RAW DATA BACKUP

Profile data collected at a site by the profiler should be backed up to a removable storage media (e.g., Zip disk). The location of the data files will depend on directory structure that is employed by the districts. The profiler should not leave a test site unless all data have been backed up. No collected profile data should be deleted from the hard disk until the district has copied the profile data to the MDT Ride Specification Share Drive.

### *4.3 RECORD KEEPING*

There are several types of records that need to be completed and kept with the profiler or at the district office and include the following:

1. Profiler Field Activity Report,
2. Profiler Maintenance / Repair Activity Report,
3. Profiler Calibration Record Sheet, and
4. Profiler Problem Report.

A description of each of these forms / reports is presented in the following sections.

#### 4.3.1 PROFILER FIELD ACTIVITY REPORT

The Profiler Field Activity Report (Appendix B) records all profiling activities at the test site. This report should be filled out for each testing day. The Profiler Field Activity Reports are kept in the profiler log book.

#### 4.3.2 PROFILER MAINTENANCE / REPAIR ACTIVITY REPORT

This form (Appendix B) should be completed when scheduled or unscheduled maintenance or repairs are performed on the profiler computer equipment or sensors.

#### 4.3.3 PROFILER CALIBRATION RECORD SHEET

Each time the full calibration check is performed on the profiler this form (Appendix B) should be filled out. The form is used to record information related to the laser sensor calibration check, accelerometer calibration, DMI calibration, and bounce test. The Profiler Calibration Record Sheets are kept in the profiler log book.

#### 4.3.4 PROFILER PROBLEM REPORT

A Profiler Problem Report (Appendix B) provides the standard format for submitting problems associated with the profiler. It is a means of tracking a problem, who is responsible for resolving it, whether or not it has been resolved, and how and when it was resolved. The Profiler Problem Report is a means for communicating about issues with the profiler between the districts and MDT headquarters.

A Profiler Problem Report must be submitted whenever there are equipment problems in the profiler, problems with data collection or data processing software, problems with data collection guidelines, or other problems related to profiling activities or profile data.

If a problem was encountered, and it was resolved, and the profiler personnel feel that this information would be useful to the other Districts, an informational problem report should be submitted. When submitting an informational problem report, indicate that the problem report is being submitted for informational purposes in the description part of the form.

# 5.0 DATA PROCESSING & REPORTING

This chapter describes the MDT Ride Specification analysis that is performed on the inertial profiler data. The profile data is evaluated for two components: roughness expressed by IRI and bumps. The analysis is performed by the profiler operator immediately after making the profile runs at the project. The IRI and bump results are reviewed for quality, additional profile runs are completed if necessary, and then the results are delivered to the EPM.

The profile data is evaluated for roughness and bumps using the ICC supplied RP090L (reporting software) and PROSCAN (profilograph analysis software). The processing is simplified through the use of the batch files, MTIRI and MTBUMP, which automate the parameters and operation of the analysis software. Copies of these batch files are contained in Appendix A.

A minimum of two profile data runs are made in each lane of the project. The profile data files analyzed have the following format: <FILENAME>.P0#, where <FILENAME> is determined from the convention described in Section 4.2.2 and "#" is the run number. The directory where the profile data files are stored on the profiler (e.g., D:\1022) is also described in Section 4.2.2 and will be denoted by <DIRECTORY> for the following sections.

## *5.1 IRI PROCESSING*

The IRI is computed in two phases. The first phase is for the quality control review by the profiler operator to assess the acceptability of the profiler data. The second phase is to report the results of the roughness to the EPM.

### 5.1.1 QUALITY CONTROL REPORT

IRI processing is automated by the MTIRI batch file. The following procedure is for determining the IRI at the easily reviewable 1 mi intervals:

1. At the DOS prompt, change to the directory containing the profile data file <DIRECTORY>.

2. At the prompt, type "MTIRI <FILENAME> #" for the lane and run to be analyzed, and press 'Enter' key to begin the analysis.

3. At the prompt, type 'I' to select the IRI Report. The other options are to process the Event Report, fix the Ascending distance values, and process the Speed Report but are not normally used in this procedure.

4. At the prompt, type 'E' to process the IRI report in English units. If the metric IRI report is desired, type 'M' instead.

5. At the prompt, type ‘3’ to process the IRI report at 1 mi intervals. If the metric IRI report is being processed, the selection is also ‘3’ to process the report at 1600 m intervals.

6. After the IRI report has been processed and printed, at the prompt type ‘Q’ to exit.

7. Repeat steps 2 through 6 to process the remaining profile data files for the other lanes and runs.

#### 5.1.2 ROUGHNESS REPORT

IRI processing is automated by the MTIRI batch file. The following procedure is for determining the IRI at the MDT Ride Specification interval of 0.2 mi (0.32 km):

1. At the DOS prompt, change to the directory containing the profile data file <DIRECTORY>.

2. At the prompt, type “MTIRI <FILENAME> #” for the first error free run in each lane to be analyzed and press ‘Enter’ key to begin the analysis.

3. At the prompt, type ‘I’ to select the IRI Report. The other options are to process the Event Report, fix the Ascending distance values, and process the Speed Report but are not normally used in this procedure.

4. At the prompt, type ‘E’ to process the IRI report in English units. If the metric IRI report is desired, type ‘M’ instead.

5. At the prompt, type ‘2’ to process the IRI report at 0.2 mi intervals. If the metric IRI report is being processed, the selection is also ‘2’ to process the report at 300 m intervals.

6. After the IRI report has been processed and printed, at the prompt type ‘Q’ to exit.

7. Repeat steps 2 through 6 to process the remaining profile data files for the other lanes.

### *5.2 BUMP PROCESSING*

Bump processing is automated by the MTBUMP batch file. The following procedure should be followed to perform the bump analysis on the profile data files.

1. At the DOS prompt, change to the directory containing the profile data file <DIRECTORY>.

2. At the prompt, type “MTBUMP <FILENAME> #” for the lane and run to be analyzed, and press ‘Enter’ key to begin the analysis.

3. At the prompt, type ‘D’ to select the Defect Report. The other options are to Graph the PROSCAN profile, process the Event File, and fix the Ascending distance values but are not normally used in this procedure.

4. At the prompt, type ‘E’ to produce the bump report in English units. If the metric bump report is desired, type ‘M’ instead.

5. After the bump report has been processed and printed, at the prompt type ‘Q’ to exit.

6. Repeat steps 2 through 5 to process the remaining profile data files for the other lanes.

## *5.3 QUALITY CONTROL REVIEW*

The operator performs a quality control review on the profile data before delivering the results to the EPM.

### 5.3.1 ACCEPTANCE OF RUNS

Once the operator is confident that a minimum of two error free runs have been obtained, the Quality Control Review and Bump Reports are used to evaluate their acceptability. Profiler runs should satisfy the following criteria:

1. The average IRI values at each 1 mi (1.61 km) interval for each of the two runs are within ± 5.7% of the mean IRI of both runs.

2. If spikes (e.g., unusually high IRI) are present in the data, the operator should determine if spikes are pavement related or the result of equipment or operator error. The operator should examine the profile bump reports for discrepancies and features that cannot be explained by observed pavement features. The operator should also be familiar with the trouble shooting guide included in Appendix C.

### 5.3.2 NON-ACCEPTANCE OF RUNS

The operator is responsible for carefully reviewing profile data to determine if a high degree of run-to-run variability is indicative of ‘bad’ data or indicative of a pavement with a high degree of transverse variability. If profile runs do not meet the criteria in Section 5.3.2, the operator should perform the following steps to determine if variability is the result of equipment errors, operator errors, environmental effects, or pavement factors.

1. Recall if any of the following items could have affected collected data: passing trucks, high winds, rapid acceleration or deceleration of profiler.

2. Review spikes to determine if spikes are result of field related effects (e.g., potholes, transverse cracks, bumps) or due to electronic failure or interference.

3. If variability between runs or spikes are believed to be operator related or equipment error, identify and correct cause(s) of anomalies and make a maximum of three additional runs until a minimum of two runs free of equipment or operator errors are obtained. Where data anomalies are believed to be caused by pavement features rather than errors, additional runs should be obtained on that lane and evaluated using the processing and reporting software. If data from the additional runs are consistent with those runs collected previously in terms of variability and presence of pavement-related anomalies, no further runs are required. If data from the additional runs differ from the previous runs, the profiler operator should re-evaluate cause of variability or apparent spike conditions.

### *5.4 DATA RESULTS DELIVERY*

Once the profiler operator has performed the quality control review, the final step is to deliver and review the results with the EPM.

A Roughness Report will be generated using the procedure described in Section 5.1.2 for the first profile run deemed to be error free for each lane profiled. This report will contain the IRI values for the left and right wheel paths at 0.2 mi (0.32 km) intervals. These IRI values will be applied to the most recent pay incentives/disincentives as described in MDT Ride Specification.

A Bump Report will be generated using the procedure described in Section 5.2 for the first profile run deemed to be error free for each lane profiled. The Bump Report will indicate the locations of potential defects. These will be reviewed with the EPM. Location should be physically examined to determine if, at the EPM's discretion, the location should be considered a defect.

### *5.5 FINAL DATA BACKUP*

After delivering and reviewing the results with the EPM, the electronic profile data files need to be backed up on the MDT Ride Specification Share Drive. All data at the project should be copied into the "Ride Data" directory for the appropriate district (e.g., D:\Butte\1002). The data should be organized in subdirectories for the year and project control number.

# REFERENCES


1. LTPP Manual for Profile Measurements and Processing, Version 4.1, May 2004.
2. International Cybernetics Corporation MDR 4080 / 4097 Mobile Data Recorder Manual.
3. 2004 AASHTO Provisional Standard, MP11-03, “Inertial Profiler”, June 2004.
4. 2004 AASHTO Provisional Standard, PP37-04, “Determination of International Roughness Index (IRI) to Quantify Roughness of Pavements”, June 2004.
5. 2004 AASHTO Provisional Standard, PP49-03, “Certification of Inertial Profiling Systems’, June 2004.
6. 2004 AASHTO Provisional Standard, PP50-03, “Operating Inertial Profilers and Evaluating Pavement Profiles”, June 2004.
7. 2004 AASHTO Provisional Standard, PP51-03, “Pavement Ride Quality When Measured Using Inertial Profiling Systems”, June 2004.

# APPENDIX A.  COMPUTER FILES

*AUTOEXEC.BAT file*

```
@ECHO OFF
C:\DOS\SMARTDRV.EXE /X
PROMPT $p$g
PATH C:\DOS;C:\MDRSW;C:\IOMEGA;C:\
SET TEMP=C:\TEMP
@SET SCSI_DRIVER = C:\IOMEGA
@SET SCSI_UTILITY = C:\IOMEGA
DOSKEY
DATE
TIME
```

*CONFIG.SYS file*

```
DEVICE=C:\DOS\SETVER.EXE
DEVICE=C:\DOS\HIMEM.SYS
DEVICE=C:\DOS\EMM386.EXE
DOS=HIGH,UMB
FILES=30
LASTDRIVE=Z
rem DEVICE = C:\IOMEGA\ASPIPPM1.SYS FILE=NIBBLE.ILM SPEED=10 Quiet
rem DEVICE = C:\IOMEGA\ASPIPPM2.SYS FILE=NIBBLE2.ILM SPEED=10 Quiet
DEVICE = C:\IOMEGA\ASPIIDE.SYS Scan Info Quiet
DEVICE = C:\IOMEGA\ASPIATAP.SYS Scan Info Quiet
DEVICE = C:\IOMEGA\SCSICFG.EXE /V
DEVICE = C:\IOMEGA\SCSIDRVR.SYS
```

*M.BAT File*

```
md090llw.exe
```

## *MTIRI.BAT File*

```
@ECHO OFF
REM            MTIRI.BAT       Batch file 4-4-2001 REOSR V 1.0
REM
REM       This batch file was written for the Montana DOT district offices
REM       to evaluate newly constructed pavements using ICC road profilers
REM       with two lasers and accelerometers. The road profile data is
REM       converted into IRI numbers using evaluation parameters established
REM       by the DOT. The procedure provides for both English and Metric data.
REM       See the Help section at the end of the batch file.
REM       Contact Bob Olenoski at ICC 727-547-0696 for any questions.
REM
  ECHO.
  ECHO Montana DOT IRI Report Batch File
  ECHO.
  IF "%1" == "/?" GOTO HELP
  IF "%1" == "" GOTO HELP
  IF "%2" == "" GOTO HELP

REM MAIN LOOP START TO CHECK TO SEE WHAT SHOULD BE DONE
:CHECKEND
  ECHO.
  Choice /c:IEASQ /n Goto: I=IRI Report, E=Event Report, A=SET ASC, S=Speed Report, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO SPD
  IF ERRORLEVEL 3 GOTO SETASC
  IF ERRORLEVEL 2 GOTO EVT
  IF ERRORLEVEL 1 GOTO STARTIRI
  GOTO CHECKEND

REM PROCESS PROFILE DATA INTO IRI REPORTS HERE
:STARTIRI
  ECHO.
  Choice /c:EMHS /n Select IRI Report Type; E=English, M=metric, H=Help, S=Skip to Event ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO EVT
  IF ERRORLEVEL 3 GOTO HELP
  IF ERRORLEVEL 2 GOTO METIRI
  IF ERRORLEVEL 1 GOTO ENGIRI
  GOTO STARTIRI

REM HERE FOR METRIC IRI REPORT
:METIRI
  ECHO.
  ECHO Metric Report Selected
  ECHO.
  IF NOT EXIST %1.P0%2 GOTO FILEHELP
  IF EXIST %1.30%2 DEL %1.30%2

:IRITYPEM
  ECHO.
  Choice /c:123Q /n Select IRI Report Interval; 1=30 Meters, 2=300 Meters, 3=1600 Meters, Q=Quit
?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO METIRI3
  IF ERRORLEVEL 2 GOTO METIRI2
  IF ERRORLEVEL 1 GOTO METIRI1
  GOTO IRITYPEM

:METIRI3
  ECHO.
  ECHO  Creating Metric IRI Report for %1.p0%2 with 1600 meter Interval
  ECHO.
  rp090l /reset /meter /filt /wav 91 /aver 0 /sectc /int 1600 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
```

```
  rp090l /meter /iri /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 15 /f9move 45 /ff
  GOTO IRICHECK

:METIRI2
  ECHO.
  ECHO  Creating Metric IRI Report for %1.p0%2 with 300 meter Interval
  ECHO.
  rp090l /reset /meter /filt /wav 91 /aver 0 /sectc /int 300 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
  rp090l /meter /iri /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 15 /f9move 45 /ff
  GOTO IRICHECK

:METIRI1
  ECHO.
  ECHO  Creating Metric IRI Report for %1.p0%2 with 30 meter Interval
  ECHO.
  rp090l /reset /meter /filt /wav 91 /aver 0 /sectc /int 30 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
  rp090l /meter /iri /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 15 /f9move 45 /ff
  GOTO IRICHECK

REM HERE FOR ENGLISH IRI REPORT
:ENGIRI
  ECHO.
  ECHO English Report Selected
  ECHO.
  IF NOT EXIST %1.P0%2 GOTO FILEHELP
  IF EXIST %1.30%2 DEL %1.30%2

:IRITYPEE
  ECHO.
  Choice /c:123Q /n Select IRI Report Interval; 1=100 Feet, 2=1056 Feet, 3=1 Mile, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO ENGIRI3
  IF ERRORLEVEL 2 GOTO ENGIRI2
  IF ERRORLEVEL 1 GOTO ENGIRI1
  GOTO IRITYPEE

:ENGIRI3
  ECHO.
  ECHO  Creating English IRI Report for %1.p0%2 with 1 Mile Interval
  ECHO.
  rp090l /reset /foot /filt /wav 300 /aver 0 /sectc /int 5280 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
  rp090l /iri /foot /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 50 /f9move 150 /ff
  GOTO IRICHECK

:ENGIRI2
  ECHO.
  ECHO  Creating English IRI Report for %1.p0%2 with 1056 Foot Interval
  ECHO.
  rp090l /reset /foot /filt /wav 300 /aver 0 /sectc /int 1056 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
  rp090l /iri /foot /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 50 /f9move 150 /ff
  GOTO IRICHECK

:ENGIRI1
  ECHO.
  ECHO  Creating English IRI Report for %1.p0%2 with 100 Foot Interval
  ECHO.
  rp090l /reset /foot /filt /wav 300 /aver 0 /sectc /int 100 /intres /iris 63360 /spdl 5 /upd
  rp090l /calprohdr user4,user5,user6,user7 /upd
  rp090l /iri /foot /spdf /if %1.p0%2 /of %1.30%2 /addsectend /f4move 50 /f9move 150 /ff

:IRICHECK
  IF EXIST %1.30%2 GOTO IRIPRT
  ECHO.
  ECHO PROGRAM ERROR; IRI Report not Created
  ECHO.
  GOTO EVT
```

```
:IRIPRT
  ECHO.
  Choice /c:PDEQ /n Output IRI Report? P=Print, D=Display, E=Event File, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO EVT
  IF ERRORLEVEL 2 GOTO EDITIRI
  IF ERRORLEVEL 1 GOTO PRTIRI
  GOTO IRIPRT

:EDITIRI
  EDIT %1.30%2
  GOTO IRIPRT

:PRTIRI
  ECHO.
  ECHO  Printing IRI Report %1.30%2
  ECHO.
  COPY %1.30%2 PRN
  GOTO IRIPRT

REM  PROCESS EVENT FILE HERE
:EVT
  IF NOT EXIST %1.E0%2 GOTO FILEHLPE
  ECHO.
  Choice /c:EMSQ /n Output Event Report? E=English, M=Metric, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO METEVT
  IF ERRORLEVEL 1 GOTO ENGEVT
  GOTO EVT

:METEVT
  ECHO.
  ECHO Metric Report Selected
  ECHO.
  IF EXIST %1.F0%2 DEL %1.F0%2
  ECHO.
  Choice /c:FNESQ /n Report Type? F=F4 F9 Moved, N=Not Moved, E=Edit Style, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO CHECKEND
  IF ERRORLEVEL 3 GOTO METEVTED
  IF ERRORLEVEL 2 GOTO METEVTNM
  IF ERRORLEVEL 1 GOTO METEVTMV
  GOTO EVT

:METEVTED
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /FF /EDIT
  GOTO PRTEVT

:METEVTNM
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /FF
  GOTO PRTEVT

:METEVTMV
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /addsectend /f4move 15 /f9move 45 /FF
  GOTO PRTEVT

:ENGEVT
  ECHO.
  ECHO English Report Selected
  ECHO.
  IF EXIST %1.F0%2 DEL %1.F0%2
  ECHO.
  Choice /c:FNESQ /n Report Type? F=F4 F9 Moved, N=Not Moved, E=Edit Style, S=Skip, Q=Quit ?:
  ECHO.
```

```
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO CHECKEND
  IF ERRORLEVEL 3 GOTO ENGEVTED
  IF ERRORLEVEL 2 GOTO ENGEVTNM
  IF ERRORLEVEL 1 GOTO ENGEVTMV
  GOTO EVT

:ENGEVTED
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /FF /EDIT
  GOTO PRTEVT

:ENGEVTNM
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /FF
  GOTO PRTEVT

:ENGEVTMV
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /addsectend /f4move 50 /f9move 150 /FF
  GOTO PRTEVT

:PRTEVT
  IF NOT EXIST %1.F0%2 GOTO FILEHLPF
:EVTOUT
  ECHO.
  Choice /c:DPS /n Display-Print Event Report? D=Display, P=Print, S=Skip ?:
  ECHO.
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO EVTPRT
  IF ERRORLEVEL 1 GOTO EDITEVT
  GOTO EVTOUT

:EDITEVT
  EDIT %1.F0%2
  GOTO EVTOUT

:EVTPRT
  COPY %1.F0%2 PRN
  GOTO EVTOUT

REM PROCESS SPEED FILE HERE
:SPD
  IF NOT EXIST %1.V0%2 GOTO FILEHLPV
  ECHO.
  Choice /c:EMSQ /n Output Speed Report? E=English, M=Metric, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO METSPD
  IF ERRORLEVEL 1 GOTO ENGSPD
  GOTO SPD

:METSPD
  ECHO.
  ECHO Metric Report Selected
  ECHO.
  IF EXIST %1.S0%2 DEL %1.S0%2
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.V0%2 /OF %1.S0%2 /FF
  GOTO PRTSPD

:ENGSPD
  ECHO.
  ECHO English Report Selected
  ECHO.
  IF EXIST %1.S0%2 DEL %1.S0%2
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.V0%2 /OF %1.S0%2 /FF
:PRTSPD
  IF NOT EXIST %1.S0%2 GOTO FILEHLPS
```

```
:SPDOUT
  ECHO.
  Choice /c:DPS /n Display-Print Speed Report? D=Display, P=Print, S=Skip ?:
  ECHO.
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO SPDPRT
  IF ERRORLEVEL 1 GOTO EDITSPD
  GOTO EVTOUT

:EDITSPD
  EDIT %1.S0%2
  GOTO SPDOUT

:SPDPRT
  COPY %1.S0%2 PRN
  GOTO SPDOUT

REM FIX ASC IN FILES HERE
:SETASC
  IF NOT EXIST %1.E0%2 GOTO FILEHLPE
  DB_EDIT %1.E0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.P0%2 GOTO FILEHLPP
  DB_EDIT %1.P0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.V0%2 GOTO FILEHLPV
  DB_EDIT %1.V0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.R0%2 GOTO FILEHLPR
  DB_EDIT %1.R0%2 C:\MDRSW\FIXASC.SCR
  ECHO.
  ECHO  ASC SET In %1.E0%2 and ASSOCIATED  .P0%2, .V0%2, AND .R0%2 Files
  ECHO.
  GOTO CHECKEND

REM NORMAL ENDING HERE
:QUIT
  ECHO.
  ECHO  Batch File Ended Normally
  ECHO.
  GOTO END

REM HELP SECTION
:FILEHELP
ECHO.
ECHO INPUT PROFILE DATA FILE %1.P0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPE
ECHO.
ECHO INPUT EVENT FILE %1.E0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPV
ECHO.
ECHO INPUT SPEED FILE %1.V0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPR
ECHO.
ECHO INPUT REFERENCE FILE %1.R0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPS
ECHO.
ECHO PRODRAM ERROR: SPEED FILE %1.S0%2 NOT CREATED, CHECK RP_ERROR.$$$
ECHO.
GOTO HELP1

:FILEHLPF
```

```
ECHO.
ECHO PROGRAM ERROR: EVENT FILE %1.E0%2 NOT CREATED, CHECK RP_ERROR.$$$
ECHO.
GOTO HELP1

:HELP
  ECHO.
  ECHO.
  ECHO This Batch file will perform the following using selections:
  ECHO.
  ECHO     1) Run RP090L to produce IRI REPORT.
  ECHO     2) Run RP090L to produce Event File Report.
  ECHO     3) Run RP090L to produce Speed File Report.
  ECHO     4) Run EDIT to display IRI and Event reports.
  ECHO     5) Print IRI and Event Reports.
  ECHO     6) Fix Data Files to set Asc instead of Dsc.
  ECHO.
  ECHO     Selections can be made for metric or english
  ECHO     and 100 feet, 1056 feet, 1 mile,
  ECHO     30 meter, 300 meter, or 1600 meter intervals.
  ECHO.
  ECHO     Fromto Parameters are not used with this batch file.
  ECHO     Use the FROMTO batch file when start and end stations are required.
  ECHO.
  ECHO.
  ECHO.
  ECHO.
  pause
:HELP1
  ECHO Usage: %0 filename n
  ECHO.
  ECHO filename  - filename to be processed in this directory
  ECHO n         - last digit of file extension
  ECHO             typically 1 when single file is created
  ECHO.
:END
```

```
@ECHO OFF
REM            MTBUMP.BAT       Batch file 4-4-2001 REOSR V 1.0
REM
REM       This batch file was written for the Montana DOT district offices
REM       to evaluate newly constructed pavements using ICC road profilers
REM       with two lasers and accelerometers. The road profile data is
REM       converted into data simulating the output of a California Profilograph
REM       which is evaluated for bumps using evaluation parameters established
REM       by the DOT. The procedure provides for both English and Metric data.
REM       See the Help section at the end of the batch file.
REM       Contact Bob Olenoski at ICC 727-547-0696 for any questions.
REM
  ECHO.
  ECHO Montana DOT Bump Report Batch File
  ECHO.
  IF "%1" == "/?" GOTO HELP
  IF "%1" == "" GOTO HELP
  IF "%2" == "" GOTO HELP

REM MAIN LOOP START TO CHECK TO SEE WHAT SHOULD BE DONE
:CHECKEND
  ECHO.
  Choice /c:DGEFHQ /n Goto: D=Defect Report, G=Graph, E=Event File, F=Fix Asc, H=Help, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 4 GOTO HELP
  IF ERRORLEVEL 4 GOTO SETASC
  IF ERRORLEVEL 3 GOTO EVT
  IF ERRORLEVEL 2 GOTO GRAPH
  IF ERRORLEVEL 1 GOTO DEFECTS
  GOTO CHECKEND

REM PROCESS PROFILE DATA INTO BUMP REPORTS HERE
:DEFECTS
  ECHO.
  Choice /c:EMHS /n Select DEFECTS Report Type; E=English, M=metric, H=Help, S=Skip to Event ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO EVT
  IF ERRORLEVEL 3 GOTO HELP
  IF ERRORLEVEL 2 GOTO METDEF
  IF ERRORLEVEL 1 GOTO ENGDEF
  GOTO DEFECTS

REM HERE FOR METRIC REPORT
:METDEF
  ECHO.
  ECHO Metric Report Selected
  ECHO.
  IF NOT EXIST %1.P0%2 GOTO FILEHELP
  IF EXIST %1.IA%2 DEL %1.I?%2
  IF EXIST %1.JA%2 DEL %1.J?%2
  IF NOT EXIST PROSCAN.MET COPY C:\MDRSW\PROSCAN.MET .
  IF NOT EXIST PROSCAN.MET GOTO HELPPM
  COPY PROSCAN.MET PROSCAN.CFG
  IF NOT EXIST RPTDESC.ICC COPY C:\MDRSW\RPTDESC.ICC .
  IF NOT EXIST PROSCAN.CFG GOTO HELPPM
  IF NOT EXIST RPTDESC.ICC GOTO HELPRI


:METDEF2
  ECHO.
  ECHO  Creating Metric PROSCAN FILES for %1.p0%2
  ECHO  Left wheel path (I) in Track 1, Right Wheel Path (J) in Track 2
  ECHO.
  rp090l /reset /meter /nofilt /aver 0 /sectc /nointc /calpro /spdl 5 /upd
  rp090l/calprohdr
filename,route,lane,operator,vehicle,user2,user3,user4,user5,user6,user7,date,time /upd
```

```
  rp090l /meter /norghct /calpro L /if %1.p0%2 /addsectend /f9move -7.6 /track 1
REM LEFT TO TRACK 1 FILES
  IF NOT EXIST %1.IA%2 GOTO HELPIA
  rp090l /meter /norghct /calpro R /if %1.p0%2 /addsectend /f9move -7.6 /track 2
REM RIGHT TO TRACK 2 FILES
  IF NOT EXIST %1.JA%2 GOTO HELPIA
  COPY %1.H0%2+%1.IA%2+%1.JA%2 %1.M0%2
  COPY %1.M0%2 ^%1.M0%2
  GOTO DEFCHECK

REM HERE FOR ENGLISH REPORT
:ENGDEF
  ECHO.
  ECHO English Report Selected
  ECHO.
  IF NOT EXIST %1.P0%2 GOTO FILEHELP
  IF EXIST %1.IA%2 DEL %1.I?%2
  IF EXIST %1.JA%2 DEL %1.J?%2
  IF NOT EXIST PROSCAN.ENG COPY C:\MDRSW\PROSCAN.ENG .
  IF NOT EXIST PROSCAN.ENG GOTO HELPPM
  COPY PROSCAN.ENG PROSCAN.CFG
  IF NOT EXIST RPTDESC.ICC COPY C:\MDRSW\RPTDESC.ICC .
  IF NOT EXIST PROSCAN.CFG GOTO HELPPE
  IF NOT EXIST RPTDESC.ICC GOTO HELPRI


:ENGDEF2
  ECHO.
  ECHO  Creating English PROSCAN FILES for %1.p0%2
  ECHO  Left wheel path (I) in Track 1, Right Wheel Path (J) in Track 2
  ECHO.
  rp090l /reset /foot  /nofilt /aver 0 /sectc /nointc /calpro /spdl 5 /upd
  rp090l                                                                   /calprohdr
filename,route,lane,operator,vehicle,user2,user3,user4,user5,user6,user7,date,time /upd
  rp090l /foot  /norghct /calpro L /if %1.p0%2 /addsectend /f9move -25 /track 1
REM LEFT TO TRACK 1 FILES
  IF NOT EXIST %1.IA%2 GOTO HELPIA
  rp090l /foot  /norghct /calpro R /if %1.p0%2 /addsectend /f9move -25 /track 2
REM RIGHT TO TRACK 2 FILES
  IF NOT EXIST %1.JA%2 GOTO HELPIA
  COPY %1.H0%2+%1.IA%2+%1.JA%2 %1.M0%2
  COPY %1.M0%2 ^%1.M0%2
  GOTO DEFCHECK

:DEFCHECK
  DIR %1.I?%2 /W
  DIR %1.J?%2 /W
  DIR ^%1.?0%2 /W
  IF EXIST %1.PSA DEL %1.PS*
  PROSCAN &%1$^%1.M0%2$RnXX$

:DEFPRT
  ECHO.
  Choice /c:RDEBQ /n Output FILE? R=Run PROSCAN to Graph, E=Event File, B=Begin, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO CHECKEND
  IF ERRORLEVEL 3 GOTO EVT
  IF ERRORLEVEL 2 GOTO EDITIA
  IF ERRORLEVEL 1 GOTO RUNPROS
  GOTO DEFPRT

:EDITIA
  EDIT ^%1.M0%2
  GOTO DEFPRT

:RUNPROS
:GRAPH
  IF NOT EXIST %1.PSA GOTO NOGRAPH
  PROSCAN
  GOTO DEFPRT
```

```
:NOGRAPH
  ECHO.
  ECHO  NO PROSCAN FILE TO GRAPH, CHOOSE DEFECT REPORT TO CREATE FILE
  ECHO.
  GOTO CHECKEND

REM  PROCESS EVENT FILE HERE
:EVT
  IF NOT EXIST %1.E0%2 GOTO FILEHLPE
  ECHO.
  Choice /c:EMSQ /n Output Event Report? E=English, M=Metric, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 4 GOTO QUIT
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO METEVT
  IF ERRORLEVEL 1 GOTO ENGEVT
  GOTO EVT

:METEVT
  ECHO.
  ECHO Metric Report Selected
  ECHO.
  IF EXIST %1.F0%2 DEL %1.F0%2
  ECHO.
  Choice /c:FNESQ /n Report Type? F=F9 Moved, N=Not Moved, E=Edit Style, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO CHECKEND
  IF ERRORLEVEL 3 GOTO METEVTED
  IF ERRORLEVEL 2 GOTO METEVTNM
  IF ERRORLEVEL 1 GOTO METEVTMV
  GOTO EVT

:METEVTED
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /FF /EDIT
  GOTO PRTEVT

:METEVTNM
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /FF
  GOTO PRTEVT

:METEVTMV
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /METER /IF %1.E0%2 /OF %1.F0%2 /addsectend /f9move -7.6 /FF
  GOTO PRTEVT

:ENGEVT
  ECHO.
  ECHO English Report Selected
  ECHO.
  IF EXIST %1.F0%2 DEL %1.F0%2
  ECHO.
  Choice /c:FNESQ /n Report Type? F=F4 F9 Moved, N=Not Moved, E=Edit Style, S=Skip, Q=Quit ?:
  ECHO.
  IF ERRORLEVEL 5 GOTO QUIT
  IF ERRORLEVEL 4 GOTO CHECKEND
  IF ERRORLEVEL 3 GOTO ENGEVTED
  IF ERRORLEVEL 2 GOTO ENGEVTNM
  IF ERRORLEVEL 1 GOTO ENGEVTMV
  GOTO EVT

:ENGEVTED
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /FF /EDIT
  GOTO PRTEVT
```

```
:ENGEVTNM
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /FF
  GOTO PRTEVT

:ENGEVTMV
  rp090l /RESET /calprohdr user4,user5,user6,user7 /upd
  RP090L /FOOT  /IF %1.E0%2 /OF %1.F0%2 /addsectend /f9move -25 /FF
  GOTO PRTEVT

:PRTEVT
  IF NOT EXIST %1.F0%2 GOTO FILEHLPF
:EVTOUT
  ECHO.
  Choice /c:DPS /n Display-Print Event Report? D=Display, P=Print, S=Skip ?:
  ECHO.
  IF ERRORLEVEL 3 GOTO CHECKEND
  IF ERRORLEVEL 2 GOTO EVTPRT
  IF ERRORLEVEL 1 GOTO EDITEVT
  GOTO EVTOUT

:EDITEVT
  EDIT %1.F0%2
  GOTO EVTOUT

:EVTPRT
  COPY %1.F0%2 PRN
  GOTO EVTOUT

REM FIX ASC IN FILES HERE
:SETASC
  IF NOT EXIST %1.E0%2 GOTO FILEHLPE
  DB_EDIT %1.E0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.P0%2 GOTO FILEHLPP
  DB_EDIT %1.P0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.V0%2 GOTO FILEHLPV
  DB_EDIT %1.V0%2 C:\MDRSW\FIXASC.SCR
  IF NOT EXIST %1.R0%2 GOTO FILEHLPR
  DB_EDIT %1.R0%2 C:\MDRSW\FIXASC.SCR
  ECHO.
  ECHO  ASC SET In %1.E0%2 and ASSOCIATED  .P0%2, .V0%2, AND .R0%2 Files
  ECHO.
  GOTO CHECKEND

REM NORMAL ENDING HERE
:QUIT
  ECHO.
  ECHO  Batch File Ended Normally
  ECHO.
  GOTO END

REM HELP SECTION
:FILEHELP
ECHO.
ECHO INPUT PROFILE DATA FILE %1.P0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPE
ECHO.
ECHO INPUT EVENT FILE %1.E0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPV
ECHO.
ECHO INPUT SPEED FILE %1.V0%2 NOT FOUND
ECHO.
GOTO HELP1
```

```
:FILEHLPR
ECHO.
ECHO INPUT REFERENCE FILE %1.R0%2 NOT FOUND
ECHO.
GOTO HELP1

:FILEHLPF
ECHO.
ECHO PROGRAM ERROR: EVENT FILE %1.F0%2 NOT CREATED, CHECK RP_ERROR.$$$
ECHO.
GOTO HELP1

:HELPPM
ECHO.
ECHO PROSCAN.MET FILE NOT FOUND IN C:\MDRSW
ECHO.
GOTO HELP1

:HELPPE
ECHO.
ECHO PROSCAN.ENG FILE NOT FOUND IN C:\MDRSW
ECHO.
GOTO HELP1

:HELPRI
ECHO.
ECHO RPTDESC.ICC FILE NOT FOUND IN C:\MDRSW
ECHO.
GOTO HELP1

:HELPIA
  ECHO.
  ECHO PROGRAM ERROR; PROSCAN FILES .IA? OR .JA? not Created
  ECHO.
  GOTO EVT



:HELP
  ECHO.
  ECHO.
  ECHO This Batch file will perform the following using selections:
  ECHO.
  ECHO     1) Run RP090L to produce 2 Track Proscan Files for Defects and Graphs
  ECHO     2) Run RP090L to produce Event File Report.
  ECHO     3)
  ECHO     4) Run EDIT to display created files.
  ECHO     5) Print Defects Report and PI Graph
  ECHO     6) Fix Data Files to set Asc instead of Dsc.
  ECHO.
  ECHO     Selections can be made for metric or english
  ECHO
  ECHO.
  ECHO     Fromto Parameters are not used with this batch file.
  ECHO     Use the ???????? batch file when start and end stations are required.
  ECHO.
  ECHO.
  ECHO.
  ECHO.
  pause
:HELP1
  ECHO Usage: %0 filename n
  ECHO.
  ECHO filename  - filename to be processed in this directory
  ECHO n         - last digit of file extension
  ECHO             typically 1 when single file is created
  ECHO.
:END
```

# APPENDIX B. PROFILER FORMS

MONTANA DEPARTMENT OF TRANSPORTATION

PROFILER FIELD ACTIVITY REPORT

MDT DISTRICT: ____________ VEHICLE ID: ____________ DRIVER / OPERATOR: ____________

DATE: ____________ TIME: ____________ TEMPERATURE: ____________

LOCATION: ____________ COUNTY: ____________ HIGHWAY: ____________

JOB NUMBER: ____________ CONTROL NUMBER: ____________ KM / MILE MARKER: ____________

| | | | Run 1 IRI Values | | | Run 2 IRI Values | | | Run 3* IRI Values | | | Run 4* IRI Values | | | Run 5* IRI Values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| File Name | Direction | Lane | Left | Right | Average | Left | Right | Average | Left | Right | Average | Left | Right | Average | Left | Right | Average |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

Runs 3, 4, & 5 to be completed only if necessary.

Number of Bridges: ____________ Location of Bridges: ____________

Additional Events / Locations of Note: ____________

Comments: ____________

MONTANA DEPARTMENT OF TRANSPORTATION
PROFILER MAINTENANCE / REPAIR ACTIVITY REPORT

MDT DISTRICT: ____________ DATE: ____________

## VEHICLE ID

MAKE: ____________ VEHICLE ID: ____________

MODEL: ____________ ODOMETER: ____________

## REASON FOR MAINTENANCE WORK (CHECK ONE)

SCHEDULED: ☐ ROUTINE: ☐

NOT SCHEDULED: ☐

## DESCRIPTION OF MAINTENANCE / REPAIR AND REASONS

# MONTANA DEPARTMENT OF TRANSPORTATION

## PROFILER CALIBRATION RECORD SHEET

OPERATOR: ______ DATE: ______

VEHICLE ID: ______ TIME: ______

LOCATION: ______

### LASER SENSOR CALIBRATION CHECK

Lens to Ground Measurement Left: ______ Right: ______

| | Measurement Action | 1 -- Left | | | 2 -- Right | | |
|---|---|---|---|---|---|---|---|
| | | 1/4" Block | 1/2" Block | 1" Block | 1/4" Block | 1/2" Block | 1" Block |
| 1 | Actual Block Thickness | | | | | | |
| 2 | Height: Floor | | | | | | |
| 3 | Height: Block | | | | | | |
| 2-3 | Height: Floor - Block | | | | | | |
| 1-(2-3) | Difference: Actual - Height | | | | | | |

Acceptable Difference Value = +/- 0.002 ft

### ACCELEROMETER CALIBRATION

| Calibration Factor (ACF) | 1 -- Left | 2 -- Right |
|---|---|---|
| Prior Value | | |
| New Value | | |

Acceptable New ACF Value = 512 +/- 10

### BOUNCE TEST

| IRI (100 ft Interval) | 1 -- Left | 2 -- Right |
|---|---|---|
| Static Value | | |
| Dynamic Value | | |

Acceptable Static IRI Value <= 5 in/mile

### DMI CALIBRATION

| Prior DCF | New DCF | Run 1 DCF | Run 2 DCF | Run 3 DCF | Run 4 DCF | Run 5 DCF | Run 6 DCF |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Acceptable Run Pulse Count Values = +/- 10 of Average Pulse Count

| Tire Pressures | Left Rear | Right Rear |
|---|---|---|
| Before Calibration | | |
| After Calibration | | |

COMMENTS: ______

| | |
|---|---|
| MDT DISTRICT: | |
| TRACKING #: | |

MONTANA DEPARTMENT OF TRANSPORTATION
PROFILER PROBLEM REPORT

| ATTENTION: | |
|---|---|
| | |
| | |

| | | | |
|---|---|---|---|
| TYPE OF PROBLEM: | | REPORTED BY: | |
| GUIDELINES: | | | |
| EQUIPMENT: | | DATE: | |
| SOFTWARE: | | | |
| NAME: | | URGENT? (Y/N) | |
| VERSION: | | | |
| OTHER: | | PAGE 1 OF | |

DESCRIPTION:

## THIS SECTION FOR USE BY MDT DISTRICT OFFICE

| | | | |
|---|---|---|---|
| RECEIVED BY: | | DATE RECEIVED: | |
| REFERRED TO: | | APPROVED BY: | |
| DATE REFERRED: | | DATE APPROVED: | |

RESOLUTION:

NOTES:

# APPENDIX C.  TROUBLE SHOOTING GUIDE

# C.0 PROFILE TROUBLE SHOOTING GUIDE

This appendix contains problems that commonly occur when collecting and reviewing profile data. Knowledge of these problems will help operators to collect better data for the MDT program. These commonly encountered problems can be grouped into the following three categories:

- Spikes in Profile Due to Equipment Problems,
- Miscalibrated DMI, or
- Early Start of Data Collection.

A brief description of each of these problem groups is provided next along with typical plots illustrating such conditions. To detect most of these problems, the profile data in question must be compared to those collected during the previous run.

## *C.1 SPIKES IN PROFILE DUE TO EQUIPMENT PROBLEMS*

Spikes can be introduced in the profile data as a result of equipment problems. These spikes can be identified by comparing multiple profile runs at a section. This comparison should be performed separately for each path of profile data. Figure C-1 illustrates the presence of a spike in the profile data. This figure shows seven profile runs of the right wheel path. Several runs have spikes and several do not have spikes. In this case, the spikes were likely due to transverse cracks.


*Figure C-1. Spikes in Profile Data.*

## *C.2 MISCALIBRATED DISTANCE MEASURING INSTRUMENT (DMI)*

A miscalibrated DMI cannot always be detected simply by comparing repeat profile runs obtained during a site visit. However, the profile runs should be plotted together to check for this phenomenon. If there is a question with the DMI, data may appear squeezed or stretched in the horizontal direction (Figure C-2). After running the calibration site, profile runs should be plotted together with previous profile runs and checked.

When this problem occurs, operator should check tire pressure of vehicle to ensure it is at the appropriate values. If the tire pressure is outside those limits, operator should adjust tire pressure and obtain a new set of measurements at the section.

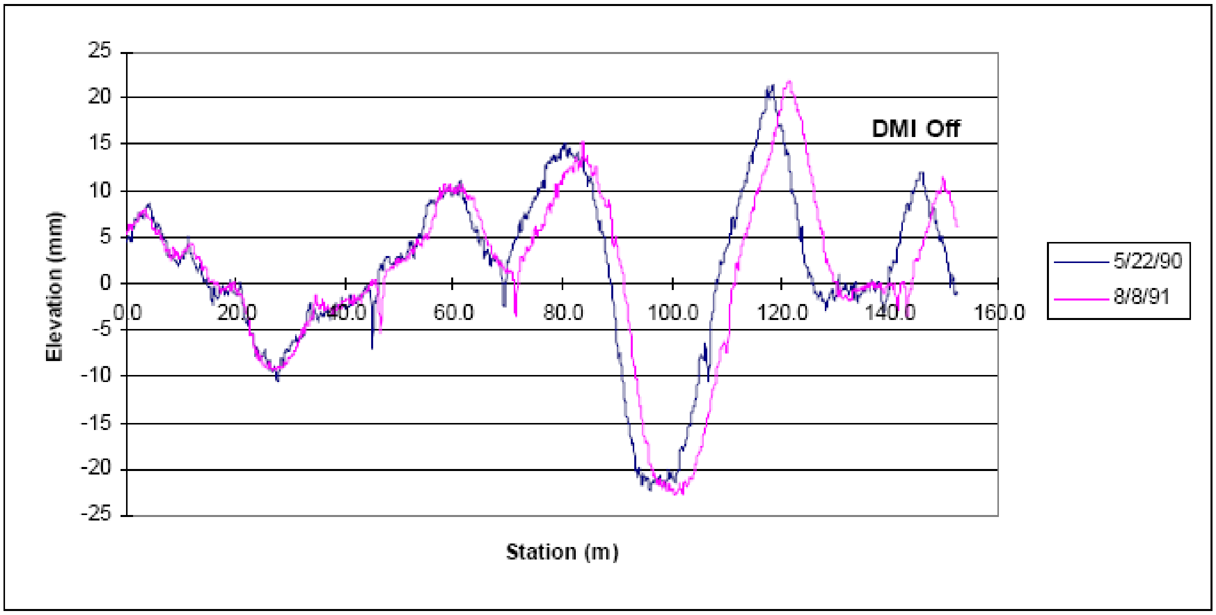


*Figure C-2. Data Collected with Calibrated & Miscalibrated DMI.*

## *C.3 EARLY START OF DATA COLLECTION*

An early profile start can occur when the photocell triggers a reference reset prior to the start of the test section. It is possible for all repeat profile runs during a visit to have the same starting location, but all are early starts. This problem can occur if there is a mark on the pavement that triggers data collection to start at the same location, but this location is before the beginning of the test section. When the current profile data are compared with those collected during an earlier visit, the early start problem can be easily identified by a clear shift in the profile data sets (Figure C-3).

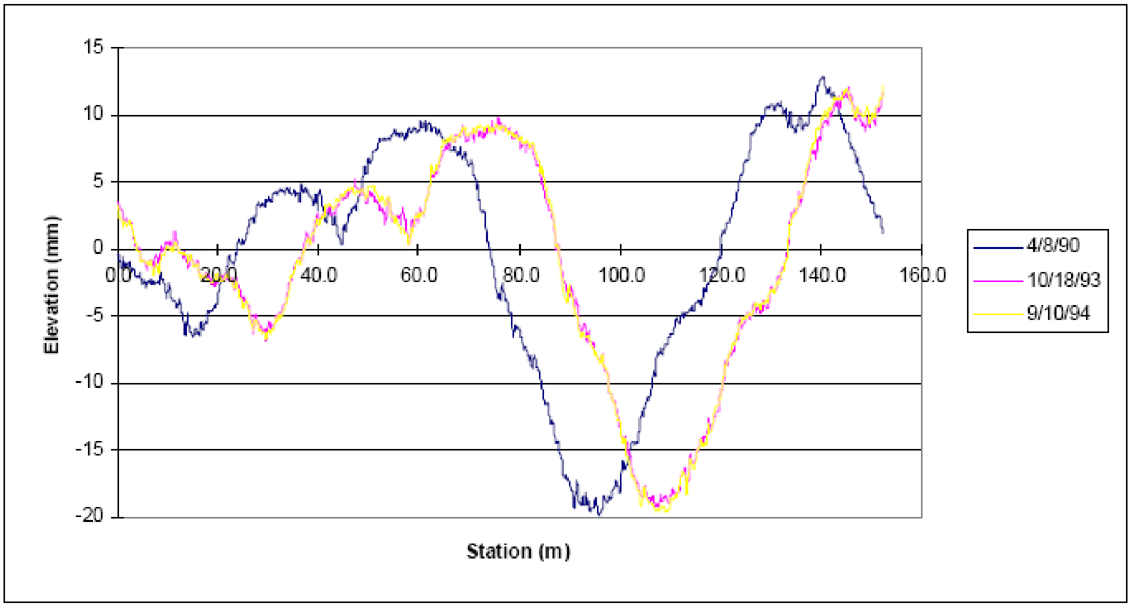


*Figure C-3. Example of Early Profile Start.*

# APPENDIX F. QC/QA PLAN

# QUALITY CONTROL & QUALITY ASSURANCE PLAN (QC/QA) FOR MDT PROFILING

JUNE 2006

Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

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# MONTANA DEPARTMENT OF TRANSPORTATION (MDT)
# RIDE DATA COLLECTION QC / QA PLAN

## 1.1 PURPOSE

The purpose of the ride data collection QC / QA plan is to insure that the procedures used by MDT in the collection and processing of ride data comply with all current MDT guidelines and result in the delivery of a quality data product. The QC / QA plan also provides for corrective actions when deficiencies are encountered and encourages actions that support continuous improvement.

## 1.2 MANAGEMENT RESPONSIBILITIES

Some of the management roles specified below can be held by the same person. Also, the management responsibilities can be instituted for each district or for the entire state. The QC / QA Manager should oversee all districts thus ensuring data collection uniformity.

Management personnel and their responsibilities in the ride data product are:

- Engineering Project Manager (EPM) - Ultimately responsible that the data product complies with the ride specification program.
- Profile Coordinator - Responsible for all aspects of the profile data product including scheduling, data collection, and processing procedures. The Profile Coordinator must be thoroughly familiar with the field data collection activities from the operation of the profiler to the field quality checks. This person must also be thoroughly familiar with the data processing procedures. This person is the chief problem solver and trouble shooter.
- QC / QA Manager - Responsible for developing and implementing procedures for compliance of all current MDT guidelines. For the ride data product, this includes regular reviews of the field data collection and office data processing procedures, documentation, and reporting of findings and follow up reviews to determine if corrective actions have been implemented and whether they are effective.

## 1.3 STAFF REQUIREMENTS

Some of the roles specified below can be held by the same person. The staff positions and responsibilities involved in the ride data product are:

- Data Analyst - Responsible for evaluating ride data for quality, QC checks, and performing the incentive/disincentive calculations. Familiar with profile concepts, the processing software, and all protocols.
- Field Personnel - Responsible for operating the profiler, data collection, and data reporting in accordance with the most current MDT guidelines. This includes calibration and maintenance activities. Also, responsible for coordination of field activities with participants, and helping to solve field related problems.

## 1.4 TRAINING

The collection and processing of ride data is a specialized task that requires well-trained personnel. The following subsections detail the training program for new and existing staff involved with profiling activities.

### *1.4.1 NEW FIELD PERSONNEL*

Prior to operating a MDT profiler, field personnel will complete an extensive training program. The program will include a thorough review of the reference documents listed in Section 1.6.1 and the following items:

- Background information (history and theory) about profilers;
- Current MDT profiler including electronics, sensors, etc; and
- Paperwork required for profiler activities.

Once field personnel become acquainted with the profiler, there will be at least two weeks of operations training. Operations training will include vehicle operation, sensor calibration, vehicle maintenance, data collection, and data reporting.

There will be a thorough review of the first set of ride data and paperwork collected by the new field personnel. If there are any issues with this work, the responsible field personnel will receive additional training. The first data collection trip by new field personnel will also be subject to a review. It is the goal of MDT to resolve data collection and reporting issues as early as possible.

### *1.4.2 NEW OFFICE PERSONNEL*

Office activities include data handling and incentive/disincentive calculations using the most recent Ride Specification. Prior to conducting office activities, office personnel will receive the following training:

- The Data Analyst shall be familiarized with the ride data. Although it is not necessary, this person may have moved into this position from the field. In other cases, familiarity with the topic will be developed in the review training seminars and by working closely with the Profile Coordinator.

- The Profile Coordinator will complete the same type of profile review and operations training as the field personnel. Although it is unlikely that these individuals will collect ride data on a regular basis, an understanding of what the field personnel experience is important and may lead to improved data collection, data handling and reporting. In other cases, familiarity with the topic will be developed in the review training seminars and by working closely with the Data Analyst.

### *1.4.3 REVIEW TRAINING*

A training seminar will be conducted annually. All personnel involved in the ride data product will be required to attend. A meeting agenda will be prepared, which will cover topics such as field and office procedures, new protocols and guidelines, results of reviews, etc. All training schedules are subject to change due to software upgrades, changes in equipment, or updates to protocols.

## 1.5 PROCEDURES

Data collection, processing, and reporting procedures have been divided into two areas: field activities and office activities. Figure 1 illustrates the ride data flow and activities that are performed. The following sections describe the quality control efforts for the field and office activities.

### *1.5.1 REFERENCE DOCUMENTS*

The operations procedures are contained in a number of documents as described below. It is imperative that those guidelines are followed completely to ensure consistency in operations. These documents, on file at each MDT District, should be reviewed annually by all personnel. As new documents are received, they will be distributed to the appropriate personnel. If any documentation is unclear, questions should be addressed to the Profile Coordinator or QC/QA Manager as soon as possible. Specific problems with the procedures or software should be identified using the established problem report procedures and format.

The procedures for profile data collection are contained in the following documents:

1. MDR 4080 / 4097 Mobile Data Recorder (MDR) Operation Manual, International Cybernetics Corporation (ICC).
2. Profiler Operations Manual (POM) for MDT Profilers (most recent version).
3. MT – 422 Document (most recent version).

### *1.5.2 FIELD ACTIVITIES*

Field personnel must understand the purpose, interpretation, and significance of the data they are collecting. The goal is to collect quality data. Data with missing elements, incorrect, or incomplete information does not meet the MDT's ride program objectives.

#### *1.5.2.1 PREVENTIVE MAINTENANCE*

Preventive maintenance is routinely performed under MDT's equipment maintenance program. All profiler maintenance must be performed before mobilizing for data collection.

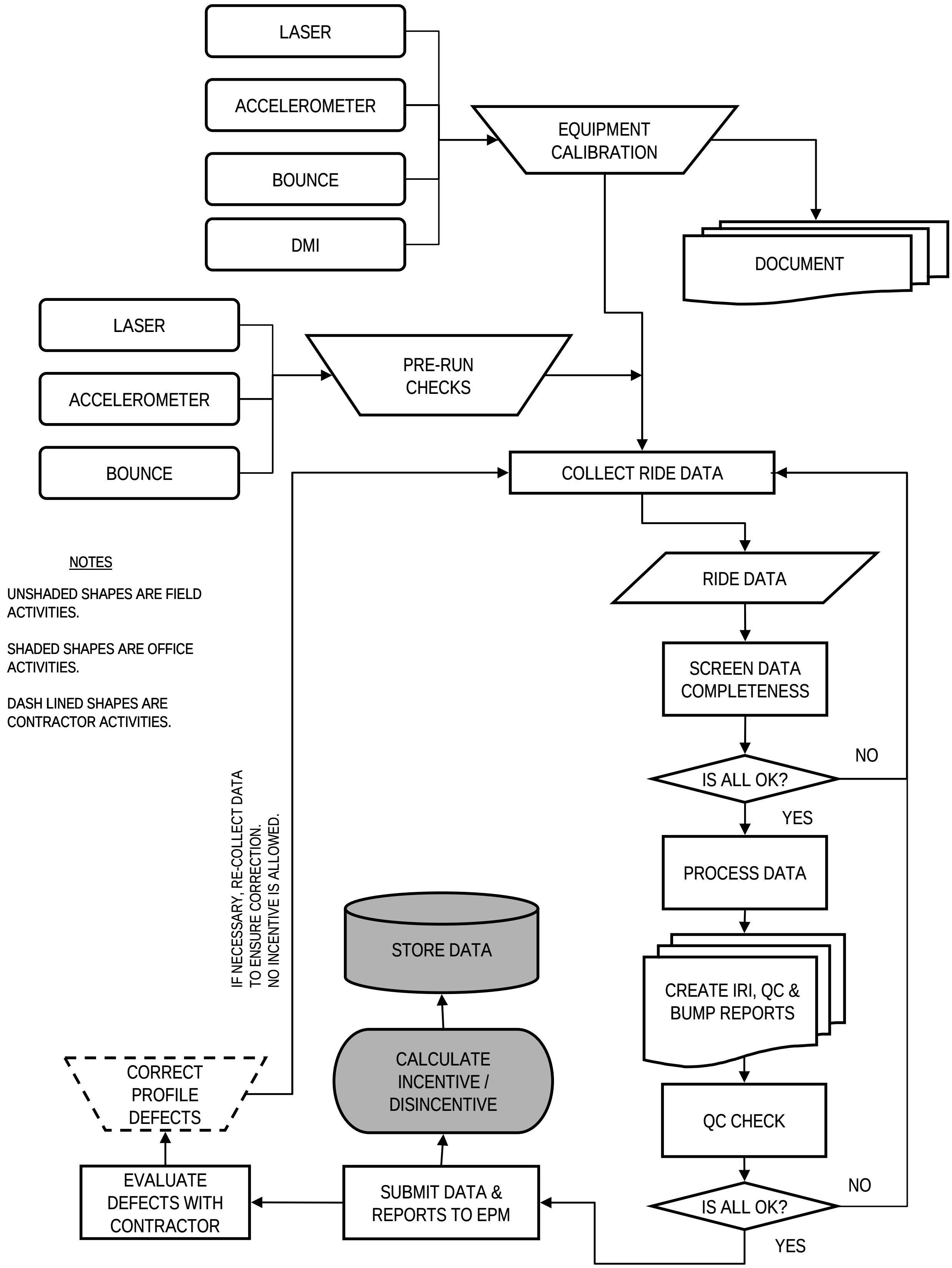


*Figure 1. MDT Ride Data Flow.*

### 1.5.2.2 Coordination

Field personnel must be prepared when they travel to the construction site. It is their responsibility to gather all required documentation forms, equipment, and instructions. Field personnel must coordinate with the EPM so that they understand the schedules and required testing. If testing occurs in conjunction with project traffic control, field personnel should coordinate activities with the EPM or resident engineer. In any case, field personnel need to have contact names in case problems arise at the project.

Field personnel must ensure all equipment is in working order and that any batteries are fully charged. Field personnel must also document and immediately report any equipment malfunctions or breakdown to the Profile Coordinator.

### 1.5.2.3 Data Collection

Data collection must follow the established procedures as outlined in the reference documents listed previously. Prior to going to the construction site, field personnel should make sure the equipment and vehicle meet the calibration requirements. Upon arrival at the construction site, the field personnel will use the construction site location layout (e.g., map) to ensure reflective tape or cones are positioned properly.

Longitudinal profile data will be collected in accordance with the most recent version of the Profiler Operations Manual (POM). Field personnel should collect at least two profiler runs. A constant vehicle speed should be maintained during the operation. Once the data has been collected, the operator should make sure that spikes can be explained. The proper file naming convention should be used.

### 1.5.2.4 Data Processing & Reporting

Field personnel process the profiler runs using the current software. Field personnel create Quality Control and Bump Reports to evaluate the profiler runs acceptability. Once the field personnel are confident the runs are acceptable, the Roughness and Bump Report are provided to the EPM.

The Bump Report indicates the locations of potential defects. These will be reviewed with the EPM and Contractor. The location will be physically examined to determine if, at the EPM's discretion, the location should be considered a defect.

The Roughness Report is transferred to the EPM for incentive/disincentive calculations.

### 1.5.2.5 Problem Documentation and Response

Any time field personnel encounter a problem with data collection, he / she should:

- Attempt to resolve the problem, immediately.
- If unable to resolve the problem, the field personnel should try to contact the Profile Coordinator for assistance. Consequently, the Profile Coordinator will have knowledge of the problem and, if it cannot be corrected immediately, will plan to resolve the problem. Either the field personnel or the Profile Coordinator should document the problem, the activities attempted to resolve it, and whether or not they were successful. The documentation should specifically state whether or not the problem was corrected, and if so, how.

- Field personnel must maintain contact with the Profile Coordinator on a continuous basis. Any feedback from the Profile Coordinator regarding the correction of previous problems must be shared among all field personnel. To accomplish this, a discussion between the Profile Coordinator and all field personnel should occur regularly (e.g., monthly during construction season).

#### *1.5.2.6 Data Storage in Profiler*

Profile data collected at a site by the profiler should be backed up to a removable storage media (e.g., Zip disk). The location of the data files will depend on directory structure that is employed by the districts. The profiler should not leave a test site unless all data have been backed up. No collected profile data should be deleted from the hard disk until the district has copied the profile data to the MDT Ride Specification Share Drive. The original copy should remain on the profiler computer until notification to delete is provided by Profile Coordinator.

### *1.5.3 OFFICE ACTIVITIES*

Like field personnel, the office personnel must understand the purpose, interpretation, and significance of the data they are reviewing and processing. The office personnel's goal is to ensure complete, logical, and quality information in a timely manner.

#### *1.5.3.1 Data Review*

The Data Analyst reviews all data upon receipt to verify that the data has been properly collected, recorded, and submitted. Before the data is entered and copied into the appropriate location, the Data Analyst should:

- Check all the documentation for correct and complete entries. If any entries are incorrect or incomplete, determine and note the causes.
- Check the file name and file size of the electronic data files.

Any problems should be presented to the Profile Coordinator and documented.

#### *1.5.3.2 Data Storage in Office*

The backup disk is transferred to the MDT Ride Specification Share Drive. Once transferred, the disk can be recycled and reused by field personnel. Additionally, original data can be deleted from the profiler.

Documentation should be filed in appropriate location at MDT District. It is the responsibility of the office personnel to ensure data can be accessed readily and proper storage procedures are followed.

#### *1.5.3.3 Data Processing & Reporting*

Office personnel utilize the Roughness Report for incentive/disincentive calculations. The incentive/disincentive calculations are based on the type of project. The appropriate pay factor equations should be obtained from EPM or most recent version of MDT Ride Specification. Office personnel should be aware of excluded portions of pavement.

Once incentive/disincentive calculations are performed, results should be filed in appropriate location at MDT District.

#### *1.5.3.4 Problem Documentation and Response*

Any time office personnel encounter a problem with the data, he / she should:

- Should document problem.
- Upon notification of a problem, the Profile Coordinator must document the receipt of the problem notification, develop a plan to correct the problem, investigate the resolution of the problem, and finally, indicate what was tried and what did or did not work. When necessary, problem resolution can be assigned to the Data Analyst or the field personnel.
- The Profile Coordinator should generate a problem report anytime a problem exists in the system. This includes hardware, software, and physical equipment used to collect and process the profile data.

## 1.6 IN-HOUSE QUALITY CONTROL REVIEWS

Quality control reviews will be performed by the QC/QA Manager or their designee periodically on the following schedule:

- New field personnel:
  — First assignment
  — Six month re-inspection
- Experienced field personnel:
  — Each staff minimum once per year
  — Responsive inspections
- New office personnel:
  — First assignment after training
  — Six month re-inspection
- Experienced office personnel:
  — Each staff minimum once per year
  — Responsive inspections

These reviews may be either announced or unannounced. Reviews will be performed both in the field and in the office. Reviews are meant to ensure the data collected, processed, and stored is of the highest possible quality. Details of the reviews specific to the field and office activities of the ride data product are outlined in the following sections.

### *1.6.1 FIELD QUALITY CONTROL REVIEWS*

Quality control reviews of the ride data collection in the field will be conducted by the QC/QA Manager. During the course of each review, field personnel are required to conduct testing operations as “typically” done, which includes coordination of personnel at the construction site, construction site safety, pre-testing or setup activities, data collection activities, and data handling activities. The reviewer will accompany the field personnel to the construction site and will observe all phases of the ride data collection process. The reviewer will not assist with any of the data collection. During the field review, the reviewer will also inspect equipment and supplies, and review activity records filed in the profiler.

At the conclusion of the field quality control review, the reviewer will document his/her findings. The report will be submitted to and reviewed with the field personnel, Profile Coordinator, Data Analyst, and EPM.

### *1.6.2 OFFICE QUALITY CONTROL REVIEWS*

Quality control reviews in the office will be conducted by the QC/QA Manager. During the course of each review, the reviewer will follow the data through all phases. The reviewer will not assist with any of the data processing but rather will comment on the process using the process flow chart in Figure 1.

At the conclusion of the office quality control review, the reviewer will document his/her findings. The review forms will be submitted to and reviewed with the Data Analyst, Profile Coordinator, and EPM.

400 copies of this public document were produced at an estimated cost of $3.56 each, for a total cost of $1,425.37. This includes $207.00 for postage and $1,218.37 for printing.